

**UNIVERSAL  
INTERCONNECTION  
TECHNOLOGY (UIT)  
WORKSHOP**

**PROCEEDINGS**

**July 25-26, 2002  
Chicago, IL**

Distribution and  
Interconnection R&D

Distributed Energy and  
Electric Reliability

U.S. Department of Energy





**Universal Interconnection  
Technology (UIT) Workshop**

**Proceedings**

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## EXECUTIVE SUMMARY

These proceedings provide the presentations and summaries of the discussions from the Universal Interconnection Technology Workshop, held on July 25-26, 2002 in Chicago, Illinois. This workshop, sponsored by the U.S. Department of Energy, Office of Distributed Energy and Electric Reliability (DEER), Distribution and Interconnection R&D, was organized to:

- Examine the need for a modular universal interconnection technology.
- Identify UIT functional and technical requirements.
- Assess the feasibility of and potential roadblocks to the UIT.
- Create an action plan for UIT development.

The UIT is envisioned as an open architecture for a standardized, highly integrated, modular interconnection technology that will come as close as possible to “plug-and-play” for all distributed energy resource (DER) platforms and a wide variety of applications. This technology would reduce costs by creating a large market for a core technology. Through firmware or software customization it would provide an expansion capability with the flexibility to adapt to a variety of needs and applications. The idea of the UIT is an outgrowth of industry feedback from a planning session at the first Distributed Power Program annual review two and a half years ago; subsequent projects with the Gas Technology Institute, Encorp and General Electric that the program has funded through the National Renewable Energy Laboratory (NREL); and the DOE/NREL DER System Interconnection Technologies Workshop held on July 24, 2001.

Industry representatives presented White Papers on UIT functions and features, present interconnection technology, approaches to modularization and expandability, and technical issues in UIT development. Individual company strategies were considered, including how well they may fit with UIT technology development. These presentations framed UIT issues that were the subject of considerable group discussion among the workshop participants.

### Major Findings

During the Workshop, several major findings and points of consensus were reached.

### UIT Definition

- Interconnecting DER with the Electric Power System (EPS) is traditionally a complicated process that can be improved, simplified, and made both more efficient and less costly by facilitating the combination of functions of previously discrete components into a more standardized, integrated, and modular approach, or modular Universal Interconnection Technology (UIT). Reaching consensus on the nature and definition of a UIT and its basic functions is an important step for the development of this technology. This consensus can be accomplished through dialogue between industry stakeholders, including DER manufacturers, interconnection component manufacturers, and UIT customers. The U.S. Department of Energy has an important role in this process, providing a platform for the exchange of information and facilitating discussion regarding the future of the UIT.
- A UIT would provide a series of functions critical for the successful integration of DER with the EPS. These functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required. As processes become more standardized, additional

economies of scale will occur in addition to increased module flexibility and enhanced functionality.

### UIT Functions and Features

- The UIT concept is analogous to personal computers – a set of core functions and capabilities is provided by the main board; flexibility, expandability, second sourcing, compatibility, and interoperability are achieved through modularity, a common bus structure and operating system, and firmware/software that can be adapted to different configurations and applications. Defining the core functions/capabilities and the common bus or system backbone structure is key.
- The core components of a UIT should provide for the minimum requirements of an interconnection system common to both inverter and non-inverter applications.
- Defining the specific functions and features to design into a UIT is of paramount importance to its ultimate development.
- General agreement was reached on the core functions that should be included in a minimum UIT configuration. These were:
  - Anti-islanding
  - Autonomous operation
  - Ability to withstand the environment in which it operates
  - Power on/ off
  - Power reset
  - Synchronization and verification
  - Import/export control
  - Voltage, frequency, phase angle, and current as key inputs to the UIT
  - VAR/power factor control
  - DER failure indicator
  - Testability (of the UIT)
  - Meeting all 1547 requirements
  - Self diagnostics
  - Non-volatile set points
- In addition to the core functions, the UIT architecture should accommodate expanded capabilities and various configurations: i.e., inverter as well as non-inverter systems; DER located near the point of common coupling (PCC) or DER located at a distance from the PCC; single DER or hybrid systems; central control as well as localized intelligence; and interface with utility dispatch, aggregators or enterprise energy management systems.
- Considering there are engineering trade-offs when building any device, the workshop participants placed particular emphasis on reliability, affordability, modularity, maintainability, and testability as key features that should be included in an optimal UIT design.
- Two paths (or subsystems) were identified: 1) Power subsystem or path; and 2) logic and control path – with communications and data links between the two paths.
- A key component of a UIT is having a controller that has a standardized interface with the other components of the interconnection system, so that different manufacturers' controllers would be interchangeable, providing flexibility, expandability and second sourcing.

### Feasibility and Potential Roadblocks

- Object models will be important for self-configuration and plug-and-play operation.

- Utility acceptance may depend on familiarity – providing a single way to interface and test from a utility point of view, i.e., standardization.
- Industry participants expressed a strong opinion that the application firmware/software should not be standardized, since this is critical to product differentiation and protecting the companies' proprietary property.

## Conclusions and Next Steps

Participants supported the concept of a UIT and felt that its adoption would result in lower costs for interconnection and increased use of DER. The group identified a series of “next steps” for moving forward with the development of a UIT. These steps include:

- Develop working definitions for each of the UIT functions identified at the workshop.
- Develop functional block diagrams of interconnection systems for a variety of DER configurations to aid in synthesizing the UIT.
- Convene a series of one-day workshops to develop a functional block diagram for the UIT and identification of the core technology.
  - One workshop to develop a functional diagram for non-inverter applications.
  - A second workshop to develop a functional diagram for inverter-based applications.
  - A third workshop to synthesize the inverter and non-inverter diagrams into a UIT and develop a UIT requirements document.
- Develop a roadmap for further defining the individual pieces within each UIT block diagram and the interfaces between them.
- Develop a list-serve for continuing discussion and work on developing the UIT.





# Universal Interconnection Technology Workshop Proceedings

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## PREFACE

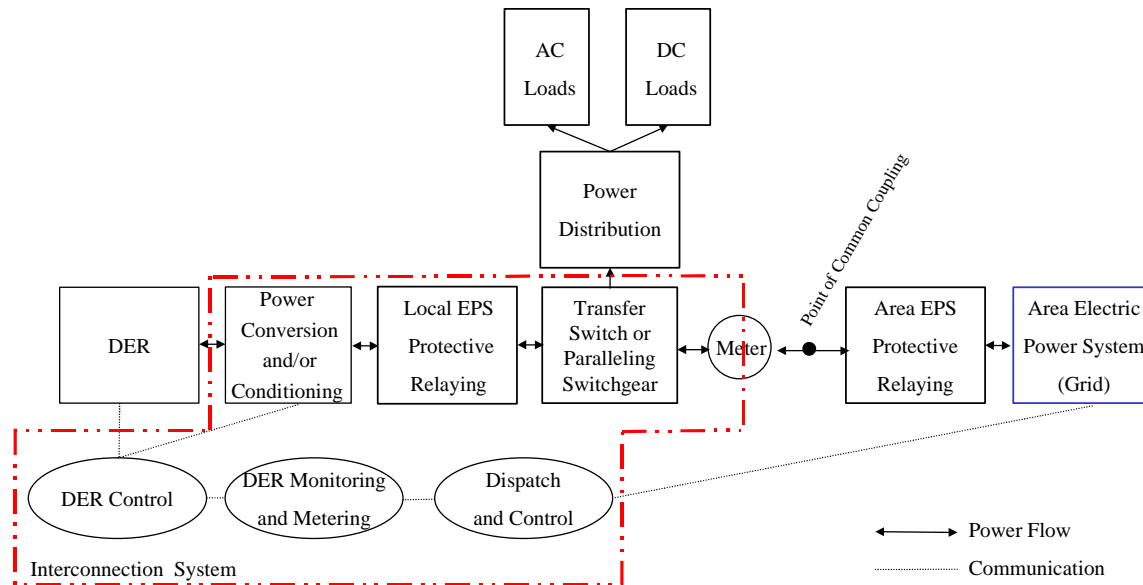
The workshop began with a welcome from *Joseph Galdo, DOE DEER*, who provided an overview of UIT background, concepts and benefits.

### ***Background on a Modular Universal Interconnection System***

Current interconnections of Distributed Energy Resources (DER) with the Area Electric Power Systems (EPS) are done through various engineering approaches using a collection of individual components. The resulting interconnection “packages” are thus not yet profiting from the numerous benefits available when the equipment utilized becomes more standardized, integrated, and interoperable. At the present time, interconnections tend to be highly dependent on the type of DER, the experience of the developer, the nature of the EPS, and the historical practices of the particular EPS operator. Electromechanical “discrete” relays, which have dominated traditional utility interconnection, protection and coordination approaches, are only beginning to be supplanted by digitally-based equipment.

At the same time, new advances in power electronics have led to the initial development of effective integration of protective relaying in inverter-based DER. Inverter-based interconnection systems are already highly integrated, solid-state, and have a high degree of functionality implemented in firmware or software. Similarly, the trend in non-inverter interconnection systems is toward increasing integration of components, using solid-state and microprocessor-based technology, with many functions implemented in firmware or software.

A distribution interconnection system consists of all of the equipment that makes up the physical link (both hardware and software) between DER and the EPS, usually the local electric distribution grid. The distribution interconnection system is the means by which the DER unit electrically connects to the electrical power system, and through such connection enables power flow in one or both directions, and can provide autonomous and semi-autonomous functions and operations supporting both the EPS and the DER facility (i.e. monitoring, control, metering and dispatch of the DER unit). Figure 1 shows the major components, with the distribution interconnection system being all the components within the dashed lines.



**Figure 1. Interconnection System Functional Block Diagram**

Program stakeholders have argued from various perspectives that the traditionally complicated “art” of interconnecting DER with EPS can be improved, simplified, and made both more efficient and less costly, by facilitating the combination of functions of previously unrelated components into a more standardized, integrated, and modular approach, or modular Universal Interconnection Technology (UIT). The goal of this activity is to develop an advanced modular UIT that would provide all of the functions within the dashed line in Figure 1. Each of these functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required. As processes become more standardized, additional economies of scale will occur in addition to increased module flexibility and enhanced functionality.

Functions that may be included in whole or part to make up a UIT system include:

- **Power Conversion and Conditioning**
  - **Power Conversion** – If necessary, the power conversion functions would change one type of electricity to another to make it EPS compatible. For example, photovoltaic (PV), fuel cells, and battery storage produce DC power and microturbines produce high frequency AC.
  - **Power Quality** – This function could provide basic power quality needs such as voltage sag support provided an adequate energy storage device is included at the site.
- **Protection Functions** – The protection functions monitor the EPS point of common coupling and the input and output power of the DER and disconnect from the EPS when normal operating conditions do not exist per IEEE P1547. (Note there is both an opportunity and an intention in the next generation of P1547 to develop procedures for maintaining DER on the grid as support.) Examples of this are over and under voltage/frequency protective setting and anti-islanding schemes.
- **Autonomous and Semi-autonomous Functions and Operations**

- **DER and Load Controls** – These control the status and operation of the DER and any local loads. The status can include on/off and power level commands. This function can also control hardware to disconnect from the EPS.
- **Ancillary Services** – These services could include: voltage support, regulation, operating reserve, and backup supply.
- **Communications** – Communications allow the DER and local loads to interact and operate as part of a larger network of power systems or microgrids.
- **Metering** – The metering function allows billing for the DER energy production and local loads.

The proposed UIT initiative rests on the premise that by combining these functions into a modular UIT, one can pursue improved system reliability and system safety plus additional functionality while reducing costs through more thorough modular systems integration.

Going beyond these required functions, some additional desirable features that might be built into a UIT system include:

- **Adaptability** - The ease with which a system satisfies differing system constraints and user needs.
- **Affordability** - To have a cost which is bearable. For a UIT system, the cost of the interconnection component is a small part of the overall installed DER system cost.
- **Availability** - The degree to which a system is operational and accessible when required for use.
- **Compatibility** - The ability of two or more systems or components to jointly perform their required functions while sharing the same hardware or software environment.
- **Dependability** - That property of a system such that reliance can justifiably be placed on the service it delivers.
- **Extendability or Expandability** - The ease with which a system or component can be modified to increase its storage or functional capacity.
- **Evolvability** - The ease with which a system or component can be modified to take advantage of new (internal) software or hardware technologies.
- **Flexibility** - The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed. For interconnection systems, the ability to adapt to:
  - New types of DER prime movers,
  - Emerging storage platforms,
  - New applications (e.g., ancillary services),
  - Diverse distribution systems,
  - New communications protocols.
- **Generality** - The degree to which a system or component performs a broad range of functions.

## Preface

- Interoperability - A system than can exchange information with and use information from other systems.
- Modularity - A modular interconnection architecture divides the interconnection system into discrete components (building blocks) each performing standard functions like the following:
  - DER control,
  - Power conversion,
  - Voltage regulation,
  - Power quality,
  - Protection,
  - Synchronization,
  - Communications/control with load,
  - Metering,
  - Dispatch, and
  - Area EPS communications and support.

The definitions of the modules should be generic enough to apply to both inverter and non-inverter systems, so that they have common building blocks. Not all interconnection systems will require all blocks.

- Maintainability - The ability of a system, under stated conditions of use, to be retained in, or restored to, a state in which it can perform a required function.
- Modifiability - The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined.
- Portability - The ease with which a system or component can be transferred from one hardware or software environment to another.
- Reliability - The ability of a system to perform a required function under stated conditions for a stated period of time.
- Scalability - The ability to incrementally add functionality to a system without replacing it completely. Scalability means that an interconnection system designed for one application (e.g., peak shaving) may be “scaled up” by adding additional modules for a more complex application (e.g., utility dispatch).
- Survivability - The degree to which essential functions are still available even though some part of the system is down. The system withstands significant electrical voltage and harmonic disturbances.
- Vulnerability - The degree to which a software system or component is open to unauthorized access, change, or disclosure of information and is susceptible to interference or disruption of system services.

To further plan coordinated UIT research, then DOE expects to prepare a technology roadmap for the UIT. The idea of the UIT is an outgrowth of industry feedback from a planning session at the first Distributed Power Program annual review two and a half years ago; subsequent projects with the Gas Technology Institute, Encorp and General Electric that the program has funded through

the National Renewable Energy Laboratory (NREL); and the DOE/NREL DER System Interconnection Technologies Workshop held on July 24, 2001. This earlier workshop reviewed the status of systems interconnection technology to determine the technology R&D needed to achieve the Distribution and Interconnection R&D's objective of a universal plug-and-play P1547-compliant interconnection technology that is applicable across DER technologies. Further work will continue to assess both the feasibility of a UIT and any potential roadblocks to its development.

## INTRODUCTION

### ***Welcome and Opening Remarks***

*Paul L. Lemar, Jr., Resource Dynamics Corporation,<sup>1</sup>* opened with a presentation on “UIT Concept and Benefit Overview.” A basic definition of the UIT was provided. Goals of the Workshop were outlined, and included:

- Examine the need for a modular universal interconnection technology.
- Identify UIT functional and technical requirements.
- Assess the feasibility of and potential roadblocks to the UIT.
- Create an action plan for UIT development.

It was also anticipated that through discussion, the group would be able to describe and prioritize efforts and identify “show stoppers” to UIT development and how to overcome them.

Throughout the workshop, participants were encouraged to discuss the UIT from the “big picture” level, but also to include specific design issues, to address marketplace needs and challenges, and determine how UITs can help lower many of the current barriers to DER.

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<sup>1</sup> Mr. Lemar's presentation can be found in Appendix A.





## UIT FUNCTIONS, NEEDED FUNCTIONALITY, AND FEATURES

### ***Presentations***

*Dr. Sam Ye of GE Global Research Center* began this first segment of the Workshop with his presentation, entitled “Universal Interconnect Needs and Trends.”<sup>2</sup>

Points made during the course of this presentation included:

- It is important to include the utility perspective in UIT development. UIT equipment vendors must be able to answer in the affirmative to the question “can you provide functions that the utility requires?”
  - This can be difficult because there is no single acceptance standard for interconnection systems – each distribution company has difference requirements.
  - The infrastructure issue becomes more prevalent as DER penetration continues. One or two DER interconnections probably will not affect the T&D system, but distribution companies begin to get nervous as the number of interconnections increase.
  - Small size DER units cause less utility discomfort than larger DER units.
- A UIT is important for high DER penetration to provide a specific, simple solution for interconnection.
  - Counter to this, standardization of interconnection is not necessary unless DER penetration will increase in the future.
- The key to the UIT is modularity. A UIT that includes all functions can be too costly for customers who do not require these functions, so modularity can help make interconnection more affordable.
  - Design a common platform with add-ons based on the DER application.
  - For software, the same code would be used with different levels of complexity.
  - The “Voice of the Customer” is important in designing a UIT.

Following the presentation, attendees asked a series of questions. These included:

- How does the GE system incorporate smaller residential customers?  
Smaller customers are provided for by focusing on designing a common platform with add-ons based on the DER application. For software, the same code would be used with different levels of complexity.
- How do utility standards play a part in UIT development?  
These were noted as quite important as, without standardization, utility requirements ultimately decide the nature of the interconnection system.

*Scott Castelez, Encorp*, followed with his presentation on “Emerging DER Networks.”<sup>3</sup> Points made and raised in this presentation included:

- Encorp does not have an inverter vs. non-inverter mindset, rather they have a system that can work with both tracks.
  - This is especially important as approximately 80+ percent of DER is non-inverter based.

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<sup>2</sup> A copy of Mr. Ye’s presentation is included in Appendix A

<sup>3</sup> A copy of Mr. Castelez’s presentation is included in Appendix A.

- The company employs a “one box” approach of taking existing functions, making them into firmware, and putting them together.
- They utilize components from other companies (e.g. transfer switch from GE).
- Interconnection is still a specialty industry.
- It is important to incorporate federal regulators and legislators in the UIT development process, as “policy developments must proceed hand-in-hand with technology.”

During and following the presentation, workshop participants asked a series of questions. These question, and selections from Mr. Castelez’s responses, included:

- How does Encorp deal with utility requirements?  
Generally, they seek approval on a case by case basis. However, if it looks like it will take too long, they will go out to a larger firm (e.g. Basler for relays) so that they can get approval with a name the utilities are more comfortable with. This can add significant cost to the project, but shortens an otherwise lengthy approval process for those customers more concerned with time than with cost.
- How easy is it to integrate the Encorp systems with DER?  
Generally it is more customized than the company would like because no standards exist. In addition, they still have to obtain utility approval, which can require adjustments like those noted above.
- What will lead to the development of a UIT?  
Energy security concerns, the need to be green, performance based incentives, and cost performance curves driven down will lead to higher penetration of DER and development of the UIT.

During this discussion, the personal computer (PC) analogy was introduced. Participants continued to build on this analogy throughout the remainder of the proceedings. It was noted that the UIT concept is analogous to personal computers – a set of core functions and capabilities is provided by the main board; flexibility, expandability, second sourcing, compatibility, and interoperability are achieved through modularity, a common bus structure and operating system, and firmware/software that can be adapted to different configurations and applications. Defining the core functions/capabilities and the common bus or system backbone structure is key to the development of a UIT.

## ***White Papers***

White papers from both Mr. Ye and Mr. Castelez follow.

**Dr. Sam Ye, GE Global Research Center, “Universal Interconnect Needs and Trends.”**

*General Electric Company*

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# **Universal Interconnect Needs and Trends**

Prepared for  
DOE Universal Interconnection Technology (UIT) Workshop  
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Dr. Sam Ye, “Universal Interconnect Needs and Trends.” Presentation.

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## **Executive Summary**

In the future, power distribution systems now controlled by large providers of power generation will be replaced by more distributed power generation architectures where the lines of demarcation between providers and users of power are less restrictive. The industry is concerned about how existing power distribution systems can accommodate such a changeover within the next 5-10 years and also about how this changeover will affect the economics of power delivery and even the implementation of new power distribution architectures and controls. One of the key issues is distributed generation – electric power system (DG-EPS) interconnection, which has fundamental impacts on current EPS operation and future DG penetration.

The interconnection issue is currently being actively addressed, led by US Department of Energy, among different communities, including regulatory, research institutes, standard organizations, utilities, and DG vendors.

This white paper will address DG/EPS interconnection needs and trends from an industry perspective. A conceptual interconnect design will also be presented.

# 1. Universal Interconnect Needs and Trends

## 1.1 Interconnection Issues

Traditional non-utility generated power sources, such as emergency and standby power systems, have minimal interaction with the electric power system. As Distributed Generation (DG) hardware becomes more reliable and economically feasible, there is an increasing trend to interconnect those DG units with the existing utilities to meet various energy needs, as well as to offer more service possibilities to customers and the host EPS.

However, a wide range of system issues arise when the DG units attempt to connect to the Electric Power Systems (EPS). Major issues regarding the interconnection of DG include protection, power quality, system reliability and system operation. Another complex issue is interconnection cost, which involves equipment design, industry standards, and the local utility’s approval process. These are some of the issues that have been identified as barriers to the application of DG in the EPS<sup>4</sup>. The solutions to these technical challenges will help not only shape the future of electric power generation, transmission, and distribution systems, but will also have a profound impact on the economics.

To promote the application of distributed generation, the following steps need to be taken. First, a widely accepted interconnection standard is needed that will allow for a standardized, cost effective interconnection solution. The IEEE SCC21 P1547 standard working group is currently working towards this goal. Second, new technical requirements that address the emerging needs of DG for dispatch, metering, communication and control should be fully explored. These additional features will improve the value of DG and the performance of the system.

## 1.2 Current Interconnect Status

The complexity of the DG/EPS interconnect interface increases with the level of interaction required between the DG units and the grid.

- Standalone only - There is no interaction with grid. No interconnect is required.
- Standby – DGs do not directly interface with the utility grid, but are connected to the local system when the utility grid is not available. Therefore, the DG has minimal interaction with grid. In this case, a transfer switch can be used as the interconnect.
- Generation of power for consumption solely for the local load: this type of DG is fully interconnected to the grid. It normally does not export power to the grid.
- DG with import/export power – this type of DGs has complex interconnect requirements. These DGs are normally integrated in the EPS control/monitoring.

To meet the above application needs, a variety of interconnect products are available in the market. They can be categorized as: power-carrying devices (PCD), protection and control devices, and inverters.

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<sup>4</sup> National Renewable Energy Laboratory, “Making Connections: Case Studies of Interconnection Barriers and Their Impact on Distributed Power Projects,” US Department of Energy, May 2000.

### **1.2.1 Power-Carrying Devices**

The power-carrying devices include switchgears such as, circuit breakers, automatic paralleling/transfer switches, etc., as well as transformers for the purpose of isolation or grounding. While the major purpose of the power-carrying devices is to conduct and break current, some of the devices have incorporated some protective functions as well. The power rating of these devices can range from several kVA to a few MVA.

### **1.2.2 Protection and Control Devices**

The protection and control devices include generator controllers, protective relays, etc. Increasingly, these functions are implemented by a class of device known as an intelligent electronic device (IED). These devices are microprocessor-based for programmable control and protection, such as synchronous checking, over/under voltage, over/under frequency, directional power, directional reactive power, reverse phase/phase-balance current, phase sequence voltage, voltage-restrained over-current protections, etc. Some of them have communication capabilities. Most of them, however, do not have dedicated anti-islanding control. These devices do not directly switch or otherwise directly handle the power. They are used together with power carrying devices to execute their protective and control functions.

### **1.2.3 Inverters**

Another DG component important to the interconnection is power electronics inverters. The inverter is used as power-carrying devices to interconnect DG energy sources, which produce DC, or produce AC at other than 60 Hz, with the grid. It is possible to implement most protective and control functions required for interconnection onto a single board that also controls inverter operation.

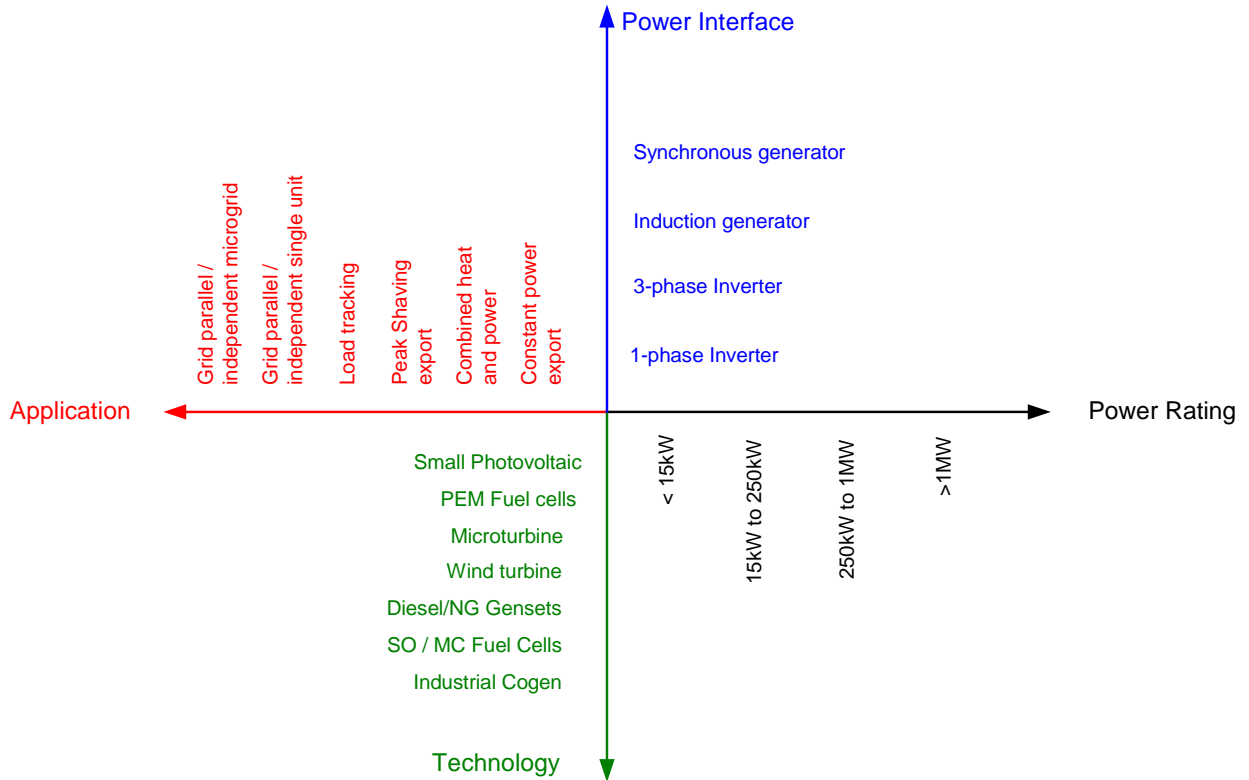
Generally, utilities have less confidence in the protective functions integrated into the inverters because these devices are not utility-grade protection hardware, and because the protective functions are not independent from the power components that could possibly fail in a way that adversely affects the grid system.

Currently, there are different standards and requirements in different states for DG interconnection. It is essential from the points of view of universality, modularity, and scalability to have a solution that addresses those requirements as shown in a multi-dimensional space in Figure 1. The DG technology can range from small photovoltaic units to large cogeneration plants. The power interface between the DG prime mover and the grid can be single-phase or three-phase power electronic converters, or rotating machines. The power range can be from under 5kW to greater than 500kW for larger systems.

There are multiple technology dimensions in DG applications. Regulatory and market forces will drive different aspects of the technologies selected. Each stakeholder will try to minimize the interconnect cost and maximize the benefits from its own perspective. This situation could result in one or two parties incurring minimal costs, while the cost is not acceptable for other parties. Eventually, it will prohibit DG achieving widespread acceptance in practical applications.

In order to achieve the broadest benefits from DG, regulators and markets, including those who set the interconnect standards, have to provide the correct price signal. Those laying out capital for an interconnection will seek to incur the least cost possible by providing the bare minimum functionality required to allow their DGs to meet safety and reliability requirements. This minimum functionality may not adequately serve the broader needs of the power system, and so, economic rewards need to be provided to those bearing the cost in order to assure that the additional functionalities beneficial to all are implemented.





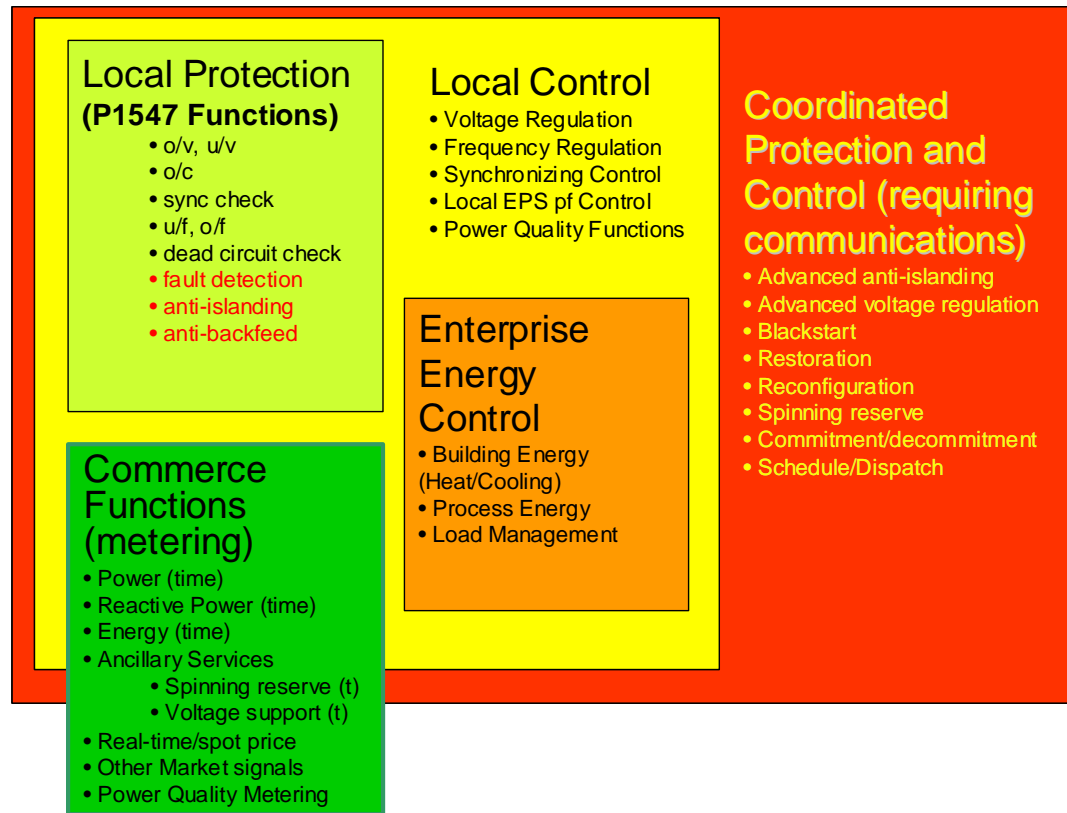
**Figure 1. DG in a multi-dimensional space**

It is observed that many solutions are targeted for specific applications. For example, some solutions are targeted for photovoltaics, while some solutions are especially suitable for rotary DG. Furthermore, it is observed that few solutions are designed such that they can be used as building blocks for providing solutions for future requirements. The goal of a new interconnect solution is to minimize overall system cost and to maximize value to the individual DG owner and the grid users in general.

### 1.3 Future Interconnect Needs and Trends

A conceptual design that addresses a technology neutral, modular, scaleable solution is desirable for the future interconnect solution. For widespread acceptance in the market, the solution has to involve a low cost approach. Existing solutions are so far not able to satisfy all requirements addressed in the multi-dimensional space shown in Figure 1. However, it should be noted that not all features would be required for all applications. Hence, a universal solution should be designed modularly, such that it can be a building block for future solutions. This would allow it to meet the need for universality, modularity, and scalability; at the same time covering all requirements addressed in the multi-dimensional space.

As noted above, a minimum of functionality may not well serve the broader needs of the power system, and yet this minimum functionality provides a basis on which to build broader, and more widely beneficial functionality. A closer examination of the requirements and benefits shows that there is a natural progression of functionality of the universal interconnect. Figure 2 shows a diagram representing the increasing levels of functionality that are required for interconnection.



**Figure 2. Global functionality of universal interconnection**

In general, each subsequent stage of complexity wholly incorporates the functionality of the previous level. This overall, long-term concept consists of following levels:

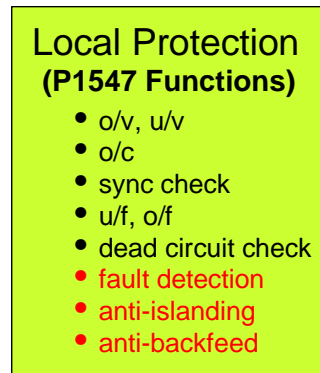
- Local Protection
- Local Control
- Coordinated Protection and Control
- Enterprise Energy Control
- Commerce

Each of these levels imposes functional requirements, which are examined in some detail in the following subsections.

### 1.3.1 Local Protection

The most basic set of protective functions that are required for interconnection are shown in Figure 3. These functions roughly correspond to P1547 requirements. These functions can be accomplished with local measurements. Most of the functions are simple, can be accomplished with existing relay functions, and are largely met by commercially available devices. The most notable exception is that the anti-islanding and fault detection functions required by P1547 are relatively complex, and not readily available. There is no method that is effective for all circumstances. From a power system reliability perspective, these local protective functions are basically aimed at limiting potential adverse impacts of DG on the host EPS.

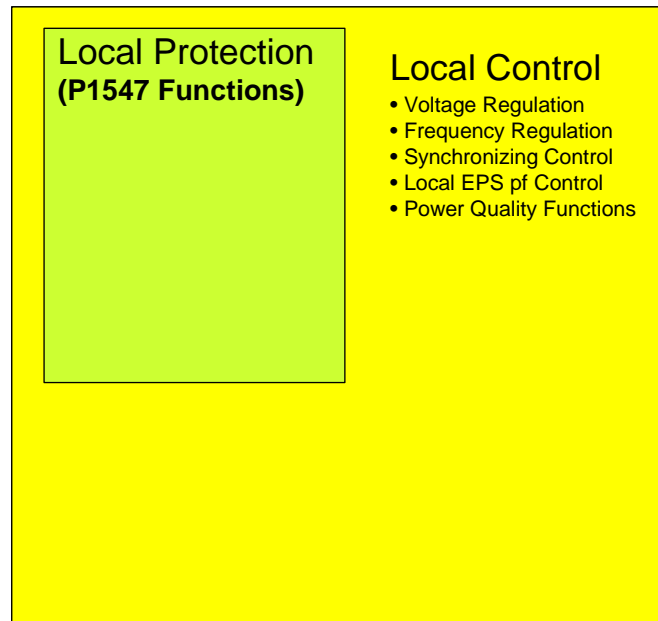
Three functions, fault detection, anti-islanding and anti-backfeed impose restrictions on the DG performance which are generally incompatible with the requirements of some of the higher level functions discussed in the next section. They are highlighted in red, to emphasize this incompatibility.



**Figure 3. Local protection functions**

### 1.3.2 Local Control

These are local functions, but include a range of controls that increase the value of the DG asset. The functions, shown in Figure 4, push the DG performance in the EPS further.



**Figure 4. Local control functions**

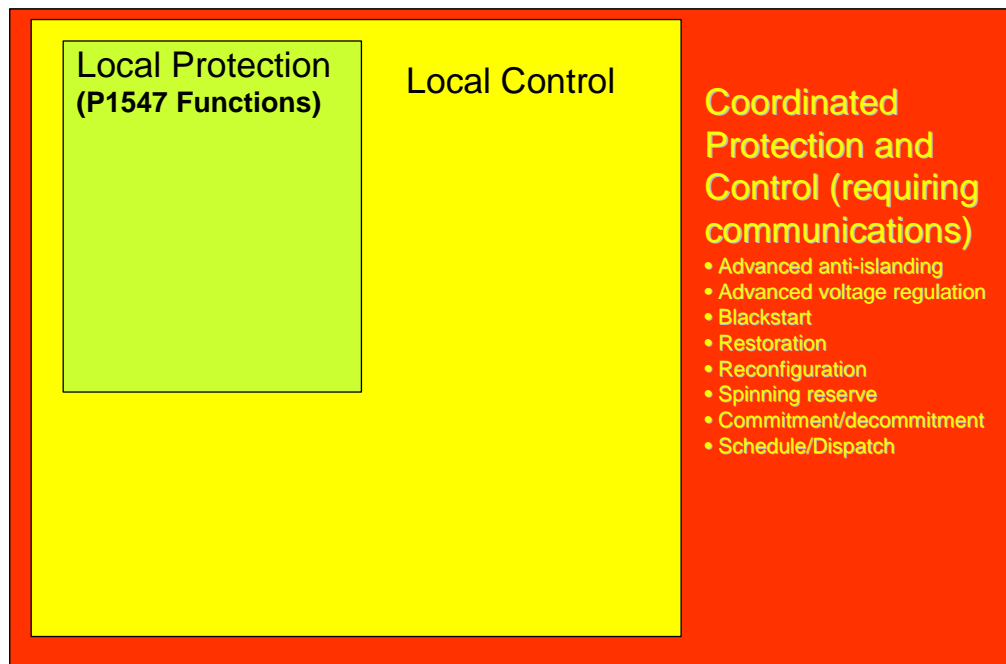
They represent requirements that may be incompatible with P1547, though most of them could be incorporated in the DG. Further study would be required to determine exactly which control functions need to reside in the interconnect. From a reliability perspective, these functions provide the potential for improvements for the local EPS. These functions are basic to the operation of a local EPS when separated from the area EPS. For grid parallel operation, these capabilities have the potential to be either beneficial or disruptive to the reliability and operation of the area EPS. Regulation functions, both voltage and frequency, are largely incompatible with the anti-islanding and anti-backfeed provisions of P1547. To fully realize system benefits, this level of the interconnect may require relatively sophisticated

means of selecting or even determining the most appropriate control mode. Other value adding functions, most notably controls aimed at improving local EPS power quality, can be included at this level.

### 1.3.3 Coordinated Protection and Control

The ability of DG to be incorporated into a distribution system using only local measurements is very limited. Many protection and control concerns cannot be addressed without communication. The distinction between protection and control becomes unclear in a networked system, and so there is little value in making the distinction.

This level of functionality, as shown in Figure 5, represents the range of functions that would be needed to make a system with significant DG penetration function properly and reliably.



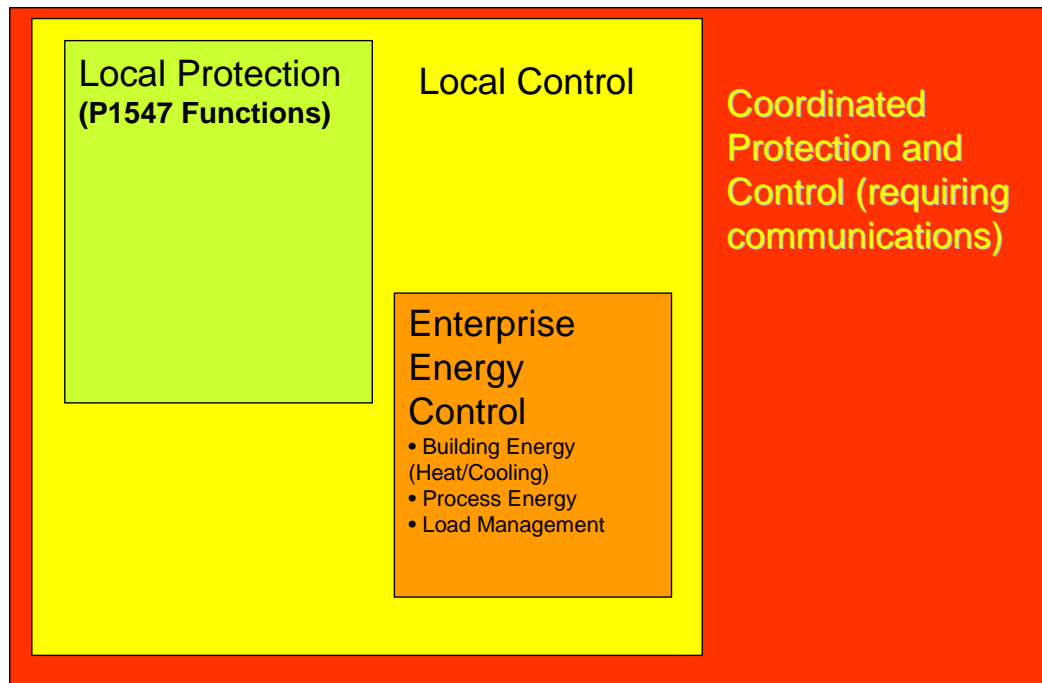
**Figure 5. Coordinated control and protection functions**

This level of functionality could include microgrids. All the functionality included in the level is aimed at improving performance and reliability of the electrical system (area EPS). The need for coordinated protection and control is especially acute from the perspective of system reliability. Networked communications are essential to the successful integration of a significant DG capacity. Regulation and restoration of systems cannot be made solely based on local signals. Economic operation of the systems, including peak shaving and more sophisticated functions such as commitment and dispatch, will require system level communication.

### 1.3.4 Enterprise Energy Control

In order to achieve the full benefit of DG, integration with other energy functions is desirable. The functions listed in this level, as shown in Figure 6, are complementary to the electrical protection and control requirements. Much of the economic analysis of DG shows that the most cost-effective system includes other aspects of energy management. Of particular interest is space heating and cooling, but other energy aspects may be important as well (e.g. gas and water management). This level is shown as a

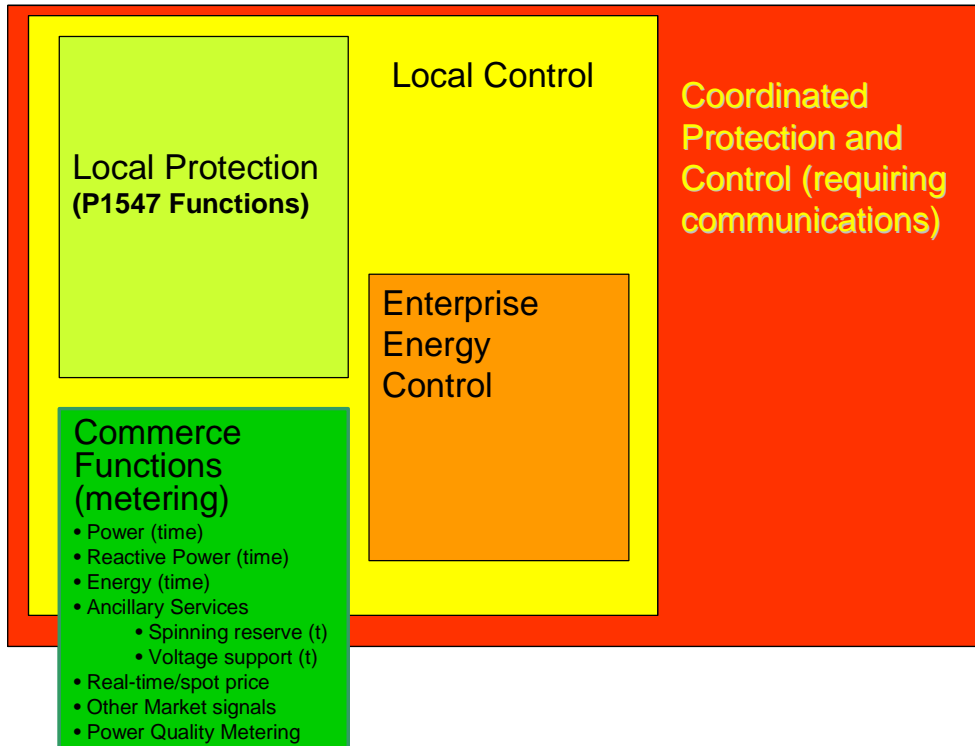
local function, e.g. for a building or a facility, but could conceptually be extended to multiple, physically separate facilities.



**Figure 6. Enterprise energy control functions**

### **1.3.5 Commerce**

There is an entire additional layer of monitoring, metering and control that relates to the business of owning and running DG. These functions may be localized or with significant communication and central processing (e.g. a DG aggregator or marketer). The functions listed in Figure 7 may be either completely localized or incorporate a broader communication system, as suggested by the placement in the figure. Market signals may be passed to various commercial stakeholders, most notably the DG aggregator selling and buying services from system operator.



**Figure 7. Commerce functions**

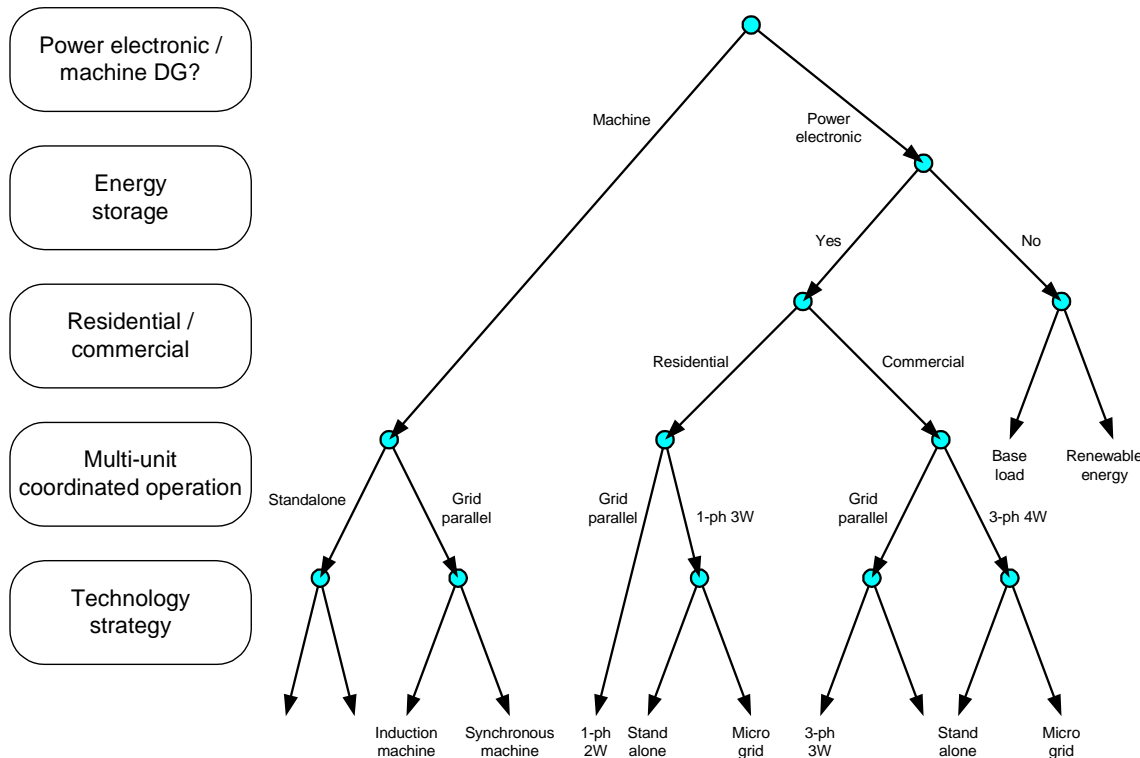
## 2. Conceptual Universal Interconnect Design

### 2.1 Interconnect Technology Roadmap

Having addressed the requirements for the universal interconnect design, the next questions that need to be addressed are:

- How can these different functionalities be implemented for a variety of solutions?
- What are the specific applications considerations that need to be addressed?
- What is the implementation of one particular instance of the universal interconnect?

Given that the functionality illustrated in Figure 2 has to be implemented in the DG space shown in Figure 1, it is necessary to identify various embodiments of the universal interconnect. It is envisaged that this can be realized with a modular core architecture that can be adapted to different configurations depending on the nature of the DG system. Figure 8 illustrates a possible method through which one can arrive at the required interconnect configuration with a minimal number of decision points. The final leaves in the tree shown in the figure will provide all the modules required to obtain all the functionality in Figure 2 for a given DG.



**Figure 8. Interconnect function decision tree**

As distributed generation hardware becomes more reliable and economically feasible, there will be a trend towards exploiting more of the features outlined in the preceding discussion. The interconnected DG units and therefore the interconnection must evolve to reflect these progressively higher levels of functionality. This increase in functional requirement provides a logical roadmap for the development of a universal interconnect. Figure 9 shows this evolution in three generations. The development of a universal interconnect utilizes a virtual test bed and a beta test site to validate each higher level of functionality.

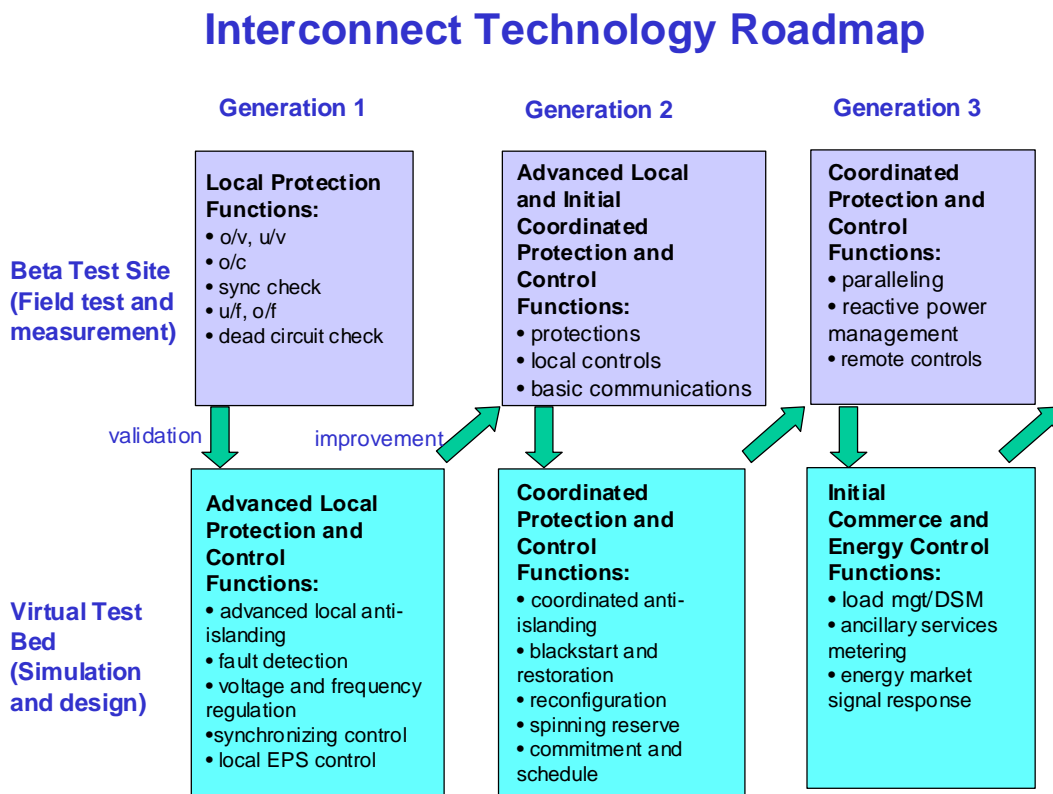


Figure 9. Interconnect technology roadmap

## 2.2 Universal Interconnect Conceptual Design

### Basic Features

This section presents a conceptual interconnect design example. As discussed above, because there are various product packages existing already for Generation 1 interconnect, the example presented here is targeting at generation 2 interconnect.

The key features are outlined below, referring to Figure 10.

- The interconnect is a standalone box to interfacing DG and grid. It is technology neutral and can be used for different DGs.



- There are two major modules in the interconnect box. One is Power Carrying Devices (PCD), and the other is Intelligent Electronic Devices (IED). The interfaces between these two modules should be normalized to allow for plug-n-play.
- There are four types of interfaces, as marked in Figure 10: I1) power interface to link DG and grid; I2) measurement interface to obtain voltage, current and others status; I3) control signal interface to send/receive I/O status and controls; and I4) communication interface for the interconnect to communicate with DG and the grid.
- PCD components are chosen and placed based on application needs, such as single- or three-phase, peak shaving, critical load, etc. Figure 10 shows three circuit breakers that represent only one particular case. Besides, the ratings of these devices are determined by grid voltage and DG current ratings.
- IED is the brain of the interconnect box. All protection, control, and communication software/firmware are designed in the device.
- The functions in the IED are modular to allow for reconfiguration and upgrade.

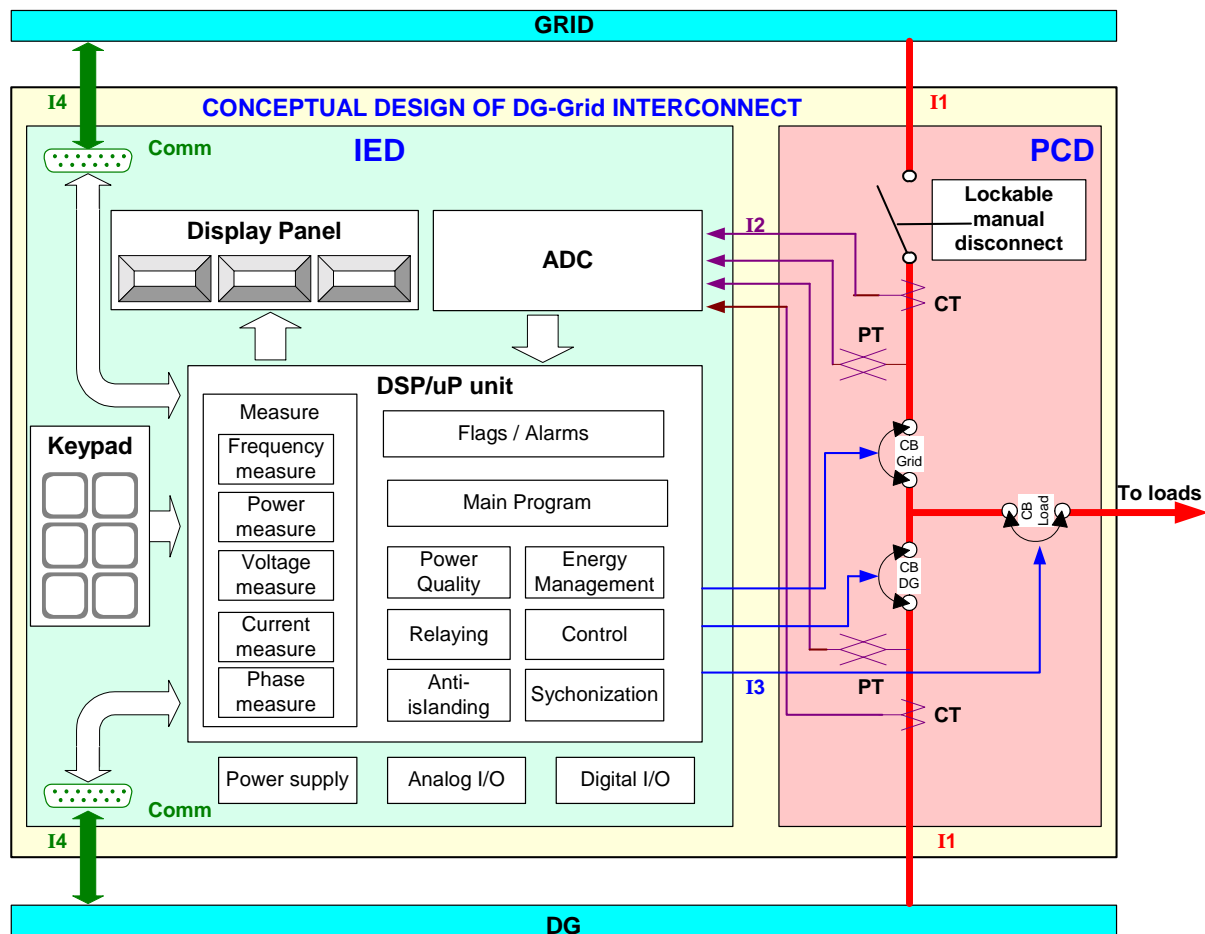


Figure 10. Conceptual interconnect design

### Interconnection Interfaces

Physically, the interconnect box is a standalone box with two types of interfaces to the DG and the grid. One is power interface, which connects the grid on one side and the DG on the other. The other one is communication interface, which links the DG locally or remotely and the grid remotely.

- **Power Interface:** The power interface could be single-phase two or three wires, or three-phase three or four wires. This will determine the number of cable/wire connections as well as sensors. Besides, the interface will determine the ratings of power-carrying devices (PCD), such as circuit breakers, and determine the ratings of sensors, such as CT and PT.
- **Communication Interface:** The communication interface is more complex than power interface. Depending on the communication needs, different communication protocols can be used. Physically, it could be wireless or wired. In order to be integrated with the grid and DG, it should have an open architecture and, at least at physical layer, be fully compatible with grid and DG communication protocols, such as RS series or Ethernet. The communication speed is dependent on the control

needs. It is also desirable that the interconnect's communication capability is upgradeable and scalable.

#### *Functional Modules*

To make the interconnect technology neutral, it is important to partition the interconnect into two major parts.

1) Power-Carrying Devices (PCD): This part includes sensors and connect/disconnect devices, such as circuit breakers, switchgear, etc. The selection of these devices depends on DG-grid point of common coupling (PCC). The grid voltage and DG power ratings must be known to select these devices. In this part, besides the power path, there are two other types of signals. One kind is sensor signals going to the IED, and the other are control signals coming out of the IED. In order to have plug-and-play and user-reconfigurable feature, the interface of these two signals must be normalized. For example, the secondary of the sensors is normalized to 120V, regardless the rating of the primary, for example 480V or 575V. The control input for the connect/disconnect devices should also be normalized. This way, the PCD and IED can be plug-and-play regardless of the voltage and current levels at the point of interconnection.

2) Intelligent Electronic Devices (IED): this part is the brain of the interconnect.

- The input to the IED includes a) sensed signals from PCD part, b) communication signals from the local DG and others, such as EPS operator, ISO, enterprise energy management systems, or other DGs, and c) manual command from keypad.
- The output of the IED is a) control signals to open / close connect / disconnect devices in PCD and b) communication signals sending to DG and grid, if the communications are two-way. The signals sent to the DG can be on/off, power command, etc. The signals sent to the grid can be power import/export data, etc. c) monitoring signals in the display panel can be power, energy meter, harmonics, etc.
- These inputs and outputs will be processed by digital signal processors (DSP) through A/D and D/A converters. Inside the DSP, different functions needed for the interconnection are programmed. These functions include
  - Computation of frequency, power, etc. as measurement function. The measurement can be used for display, computing other data, and even accessible remotely as log data for DG and grid operators.
  - Protective relaying function, such as over/under voltage, over/under frequency, etc. These relay functions are adjustable to meet different requirements and application needs.
  - Synchronization function: Before the DG connects to the grid, the DG output voltage and frequency should be synchronized. This function will sense the grid voltage and frequency and compare them with DG output voltage and frequency. When they are matched closely enough, the function will send a command to close the power-carrying devices for interconnection with the grid. If they are not matched, instead of waiting for the DGs voltage and frequency to approach the grid voltage and frequency naturally, the interconnect may send the grid voltage and frequency signals to the DG as references for the DG to adjust its voltage and frequency.
  - Anti-islanding: this is a unique function of the interconnect box. Many schemes exist today. Most passive schemes can be done within the interconnect box, while some of them require additional hardware, for example, transmitter and receiver. Most active schemes need coordination and communication with DG controls. From modular and standardization point of

view, an effective scheme built in the interconnect box would be more desirable. This function will be a key effort for the generation 2 interconnect development.

- Control: the interconnect may need some control functions, for example, control the power factor to improve voltage regulation. The control may need to be coordinated through the local and remote communications.
  - Energy management: this is a system level function that optimizes the DG value. For example, it dispatches DG for peak-shaving or base load based on daily energy rate, which could come from utilities or Independent Service Operator (ISO) through communications. The bandwidth of this control can be very low, for example, in minutes or even hours.
  - Power quality: most standards have power quality requirements imposed on the DG and grid point of common coupling, and do not distinguish between the requirements for the interconnect and DG. One of the key values of the standardized interconnect is that it can be pre-tested and pre-certified against the standards. This feature will facilitate DG installation process. Therefore, it may be necessary for the interconnect to measure power quality, such as harmonics, DC current injection, etc. If the power quality does not meet the standards, the interconnect box can command disconnection of the DG.
- Additionally, power supplies are needed to power the chips in the IED. Additional analog I/O and digital I/O also may be needed for upgrade and expansion.

The proposed interconnect concept is modular, scalable and technology neutral. This allows for maximum flexibility when interfacing to a variety of DGs for different applications.

### 3.Summary

In summary, the development of a universal interconnect can follow a natural progression of functionality. The basic requirements imposed by the various interconnection standards, most notably IEEE P1547, provide a foundation on which higher levels of functionality can be built. These higher levels of functionality benefit both system reliability and the economics of DG. Thus, the universality of the interconnection device should be viewed as a platform on which the functions required to maximize the economic and performance benefits of DG can be built, rather than a single device that will allow all possible DG to be uniformly connected to any host electric power system.

**Scott Castelez, Encorp, "UIT Concept Challenges."**

**DOE Workshop on Universal Interconnection Technologies**

**UIT Concept Challenges**

**Presented by Scott A. Castelaz**

**Encorp Inc., Vice President – Corporate Development & External Affairs**

**July 25, 2002**

**Introduction**

In the next few years, large and robust networks that aggregate distributed energy resources (DER) such as generators, flywheels, microturbines, fuel cells, photovoltaic technologies, wind turbines, and uninterruptible power supplies will gain marketplace acceptance. By design, DER assets are often sited on the fringes of a utility distribution network. While they are close to the point of energy consumption, DER assets are not necessarily in close proximity to each other or interconnected to a common energy delivery system. Interconnection of emerging DER technologies, particularly those that are inverter-based, will become increasingly important to successfully create a robust marketplace for non-traditional generation and energy storage products.

Parallel interconnection to a utility energy delivery network is required to capture the full value of DER technologies. By design, a non-parallel installation can only create value if there is demand from a dedicated load. If a dedicated load source is idle, then the DER asset remains idle and unable to take advantage of external events. Further, a parallel interface is vital to aggregate DER components sharing the same site. Without the ability to load share, DER assets cannot be dispatched in optimal sequences. Operators of DER assets will seek the ability to prioritize dispatch sequences based on a variety of factors including operational costs, maintenance history, fuel availability and emissions output. Fuel cells, microturbines, flywheels and other DER technologies require similar bridging technologies for synchronous operations.

The remote management of multiple DER technologies is a vital component in creating a truly robust network of DER technologies. Remote management often combines both hardware and software based solutions. Many of the existing hardware based devices that can determine if a DER is on or off but fail to provide safe and dynamic system control. Yet, from a managerial perspective, networking devices should include analytical software packages that integrate fuel price, energy tariff data, and other external market data as triggers to control DER networks in optimal sequences. The control networks will not manage the DER devices in isolation but rather integrate the DER technologies with utility SCADA systems, customer meters and enterprise level management platforms. In essence, end-users will eventually demand that fuel cells, flywheel, microturbines and traditional power generation technologies become fully integrated assets inside an enterprise level resources management system such as SAP.

## **Challenges**

To create these robust networks while meeting the demands of the marketplace an aggressive research and development program undertaken by all DER stakeholders should continue. Without a universal interconnection technology (UIT) as an industry standard, end-users will not fully appreciate the benefits of DER technologies and some promising DER technologies may die in the vine without ever being fully commercialized.

### **Challenge #1 – Inverter technology integration**

#### *DC Interconnect Bus characterization/requirements*

Inverter-based prime movers such as wind turbines, microturbines, fuel cells and photovoltaic technologies should share a common standard to interoperate with each on a common bus. Defining the DC power bus characteristics (voltage, transients, time to start generating power/maximum power output, current characteristics, time to increase/decrease power) of each of these technologies is vital for aggregation of multiple generation products. Defining the DC bus requirements interface of an inverter-based controller an important step in creating and understanding the interface to a robust UIT standard design.

#### *Interconnecting multiple inverters*

Work should continue to define the optimal aggregation scenarios for inverter-based technologies to eliminate potential redundancies. Evaluation is needed to focus on the ability to chain multiple inverters together to manager higher output inverter based systems. As an example, if a single inverter based controller is capable of handling a 50KV system, can two controllers be combined to manage a 100 KV systems? This technology evaluation should include the potential sizing of controller aggregation (25KW, 50KW, 100KW, and larger). Determining the optimum controller size for inverter-based technologies will aid in a UIT interface for inverter-based technologies.

#### *Voltage support technologies required for inverter based technologies*

As time delays are critical to consider for networked applications, a study of the various voltage support technologies (batteries, super capacitors, flywheels, etc) output capacities, charging capacities and power absorption technologies (for sudden load drop offs) are required to illustrate how these technologies can interoperate with fuel cells, photovoltaic and wind-based generation technologies. An analysis is required to determine the best control segmentation between voltage support technologies and other system controllers. Further work should evaluate load characteristics to offset sudden short-term voltage changes in an inverter-based system to aid in minimizing the size of the voltage support system. Defining a common interface for these technologies will greatly aid the UIT concept development.

#### *Integration of Power Electronics and System control*

Further research is necessary to develop requirements and implementation technologies associated with interconnecting inverter-based technologies. As inverter and synchronous machines use different interconnect technologies, yet the market will demand that these two technologies interoperate in seamless harmony. Further work should also be done evaluating the potential of common requirements of interconnecting both inverter and synchronous machines

with the same technology. A volume-based cost analysis could determine if inverter based electronic relays have the potential to replace the current electro-mechanical relays used with generators. The evaluation should focus on the utility interconnection interface and technologies associated with a UIT approach.

## **Challenge #2 – Third Party Requirement**

### *Business economics and size analysis*

Similar to traditional generation technologies, the cost to parallel an inverter-based unit varies in cost with size. At a certain point, smaller units face high economic hurdles and the costs associated with interconnection become prohibitive for the majority of the residential, commercial and industrial customers. While niche market segments will seek to integrate small generators and storage devices with one another and the utility delivery system, serious consideration should be made to the disproportionately high costs of interconnecting these units with current technologies.

### *Site Integration*

Evaluation should be conducted to define the various types of devices that need to be interconnected for inverter and synchronous systems. The intent is to identify a common set of I/O technologies that would allow interconnections for site specific devices required by these two systems. This will define the common elements and features for a UIT based system.

### *Enterprise integration demands*

Owners and users of various DER technologies will seek to integrate these assets with external third-party devices, legacy IT and communications systems and price signals from the emerging energy marketplace. To create a UIT standard interface, consideration should be given to the proper number and types of I/O ports required to interconnect DER devices with external data networks.

## **Next Steps & Recommendations**

To make UIT feasible, marketplace realities must be accounted for. Clearly the energy delivery networks will be managed by utilities, RTOs and ISOs. When standards for interconnection are adopted, the first iteration such as IEEE P1547 is not enough. Enduring standards take time to create and utility stakeholders will remain influential. Development of new technologies is not enough. Significant policy challenges lie ahead. Further DG in general, and UIT in particular, must demonstrate new business models and value propositions to gain wide spread adoption.

Scott Castelez, “UIT Concept Challenges.” White Paper.



## ***Defining the UIT: Participant Discussion***

Following the presentations, an initial discussion of the UIT commenced. The following comments are some of those made by the group in a context-setting discussion.

- Components currently have overlapping and common functions, the UIT development process should look for these commonalities and how they work together.
- The UIT should be a device that helps make DER and the utility transparent to each other.
- IEEE P1547 addresses many of the issues related to UIT development and provides a starting place for a discussion of this technology.
- It may be useful to discuss UIT development in two tracks – inverter based and non-inverter based.
  - However, caution should be applied to ensure that there is not too much focus on separating the two tracks, rather progress should be made in finding commonalities and providing for flexibility between the two tracks.
- Development should look not only at the present, but at the possibilities and requirements of the future when discussing UIT functionalities and requirements.
  - The ability to hook up a new DVD player to a 12-year old television was used as an example. Though DVDs were not widely in use at the time the television was sold, the television manufacturer allowed for the possibility of future integration with this technology. The same forward thinking should be used in developing the UIT.

## **UIT Definition**

Ultimately, the following points were agreed upon by the Workshop participants. These points defined the course and direction of the remaining sessions of the Workshop.

- Interconnecting DER with the Electric Power System (EPS) is traditionally a complicated process that can be improved, simplified, and made both more efficient and less costly by facilitating the combination of functions of previously discrete components into a more standardized, integrated, and modular approach, or modular Universal Interconnection Technology (UIT). Reaching consensus on the nature and definition of a UIT and its basic functions is an important step for the development of this technology. This consensus can be accomplished through dialogue between industry stakeholders, including DER manufacturers, interconnection component manufacturers, and UIT customers. The U.S. Department of Energy has an important role in this process, providing a platform for the exchange of information and facilitating discussion regarding the future of the UIT.
- A UIT would provide a series of functions critical for the successful integration of DER with the EPS. These functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required. As processes become more standardized, additional economies of scale will occur in addition to increased module flexibility and enhanced functionality.
- The UIT concept is analogous to personal computers – a set of core functions and capabilities is provided by the main board; flexibility, expandability, second sourcing, compatibility, and interoperability are achieved through modularity, a common bus structure and operating system, and firmware/software that can be adapted to different configurations and

applications. Defining the core functions/capabilities and the common bus or system backbone structure is key.

- The core components of a UIT should provide for the minimum requirements of an interconnection system common to both inverter and non-inverter applications.
- Defining the specific functions and features to design into a UIT is of paramount importance to its ultimate development.

### ***UIT Functions, Needed Functionality, and Features: Participant Discussion***

The goal of this group activity was to discuss the functions to be included in a modular UIT. Each of these functions would be made available through various individual modules, either physical or logical, which in turn will be combinable to form an integrated interconnection system as required.

A group discussion was initiated to address these issues, and the following questions were presented:

- What minimum set of functions should be included in a basic interconnection system? What are the optional additional capability functions?
- Given engineering trade-offs, what are the key features (e.g. interoperability and compatibility, flexibility, scalability and expandability, reliability, survivability, affordability) that a modular UIT design should focus upon?

### **UIT Functionality**

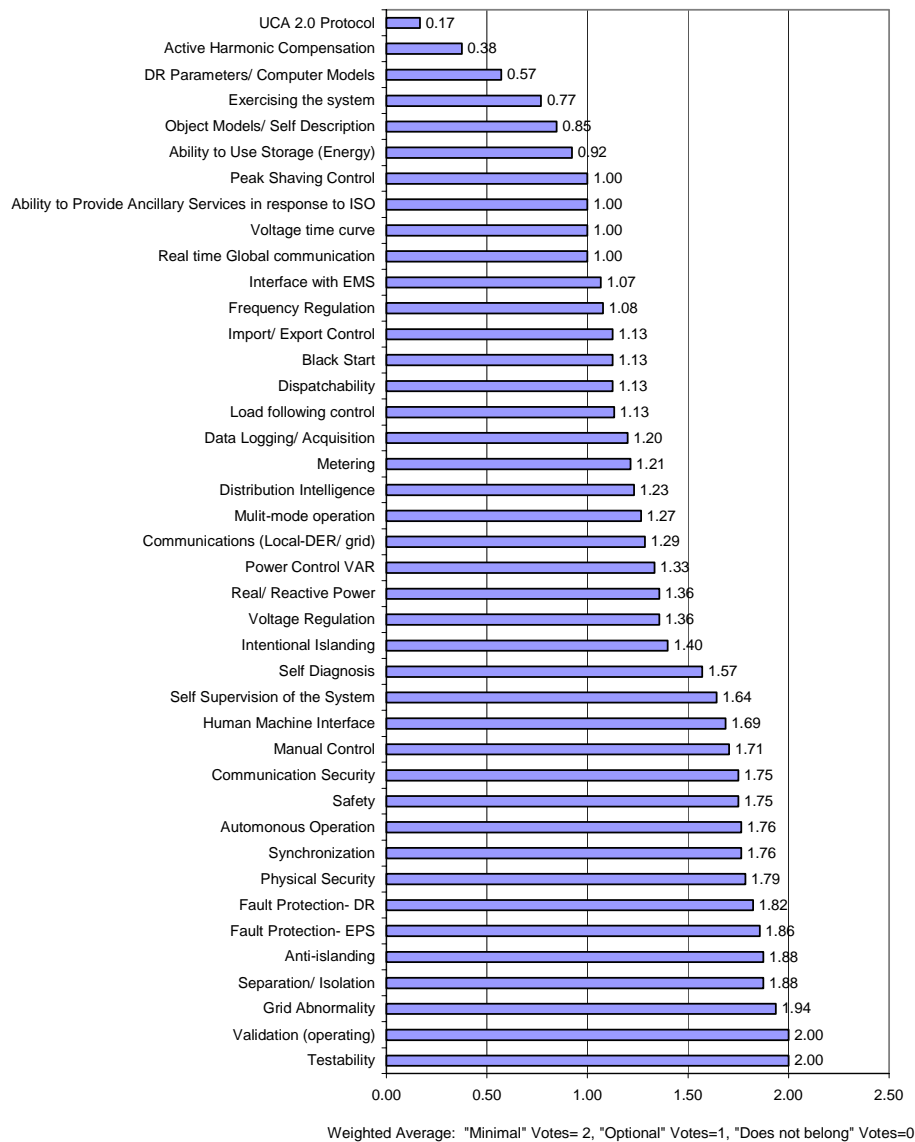
*What minimum set of functions should be included in a basic interconnection system? What are the optional additional capability functions?*

The group discussion began by asking participants to list and explain functions that could be included in a UIT. The list below was generated by participant discussion.

- |                                  |                                    |
|----------------------------------|------------------------------------|
| • Testability                    | • Intentional Islanding            |
| • Validation (operating)         | • Voltage Regulation               |
| • Grid Abnormality               | • Real/ Reactive Power             |
| • Separation/ Isolation          | • Power Control VAR                |
| • Anti-islanding                 | • Communications (Local-DER/ grid) |
| • Fault Protection- EPS          | • Multi-mode operation             |
| • Fault Protection- DR           | • Distribution Intelligence        |
| • Physical Security              | • Metering                         |
| • Synchronization                | • Data Logging/ Acquisition        |
| • Autonomous Operation           | • Load Following Control           |
| • Safety                         | • Dispatchability                  |
| • Communication Security         | • Black Start                      |
| • Manual Control                 | • Import/ Export Control           |
| • Human Machine Interface        | • Frequency Regulation             |
| • Self Supervision of the System | • Interface with EMS               |
| • Self Diagnosis                 | • Real Time Global Communication   |

- Voltage Time Curve
- Ability to Provide Ancillary Services in Response to ISO
- Peak Shaving Control
- Ability to Use Storage (Energy)
- Object Models/ Self Description
- Exercising the System
- DR Parameters/ Computer Models
- Active Harmonic Compensation
- UCA 2.0 Protocol

Voting followed in which participants were asked to distinguish between functions they consider to be minimal for inclusion in a UIT, those functions they consider optional or additional, and the features they felt do not belong in a UIT. A weighted average of these votes, in which "Minimal" votes were given a value of two (2), "Optional" votes a value of one (1), and "Does not belong" votes a value of zero (0), is shown graphically in Figure 2.



**Figure 2. Weighted Average Results of UIT Function Voting**

## Defining the UIT: Participant Discussion

A second tier discussion followed voting in which participants were asked to develop a final list of basic functions to be included in a UIT. After much debate about what a UIT is and what it needs to be, a general agreement was reached on minimal UIT functionality. These functions should be included in any future discussion of immediate UIT development. This list included:

- Anti-islanding
- Autonomous operation
- Ability to withstand the environment in which it operates
- Power On/ Off
- Power reset
- Synchronization and verification
- Import/export control
- Voltage, frequency, phase angle, and current as key inputs to the UIT
- VAR/Power factor control
- DER failure indicator
- Testability (of the UIT)
- Meeting all 1547 requirements
- Self diagnostics
- Non-volatile set points

The group came up with several additional capabilities and indicated that, although they did not consider them basic functions, these capabilities should be considered in the longer term outlook for UITs. These additional capabilities included:

- Intentional islanding
- Physical security
- Cyber security
- Manual controls (i.e. manual synchronization, manual testing)
- Modes (load shed, peak shave, stand alone)
- Metering (revenue, utility grade)

Comments were made regarding several of these functions.

- Intentional islanding was designated a future function that will be application driven. Participants commented that a definition of the intentional islanding function versus the stand-alone function should be made clear.
- Physical security was determined to be important, but fundamental to the prime mover rather than the UIT itself. However, the ability to physically remove communication keys from the UIT should be considered and guarded against.
- Cyber security will also gain in importance in the future as, since these units will be hooked up to the grid, there will be cyber requirements to address homeland security concerns.
- Testability, which confirms the operation of the UIT, is also a major adoption issue for utilities.

The group determined that, in addition to the core functions, the UIT architecture should accommodate expanded capabilities and various configurations: i.e., inverter as well as non-inverter systems; DER located near the point of common coupling (PCC) or DER located at a distance from the PCC; single DER or hybrid systems; central control as well as localized intelligence; and interface with utility dispatch, aggregators or enterprise energy management systems.

## UIT Features

*Given engineering trade-offs, what are the key features (e.g. interoperability and compatibility, flexibility, scalability and expandability, reliability, survivability, affordability) that a modular UIT design should focus upon?*

Following the discussion on UIT Functions, a list of 18 example features and their basic definitions were given to the participants. These definitions are provided in the Preface of this document.

Drawing from and adding to this list, and considering there are engineering trade-offs when building any device, the workshop participants placed particular emphasis on reliability, affordability, modularity, maintainability, and testability as key features that should be included in an optimal UIT design. Throughout the discussion, participants noted that while some features are complementary (such as modularity and affordability), others features will likely be achieved only in opposition to or at the expense of each other (i.e. in some instances, achieving affordability can compromise reliability).

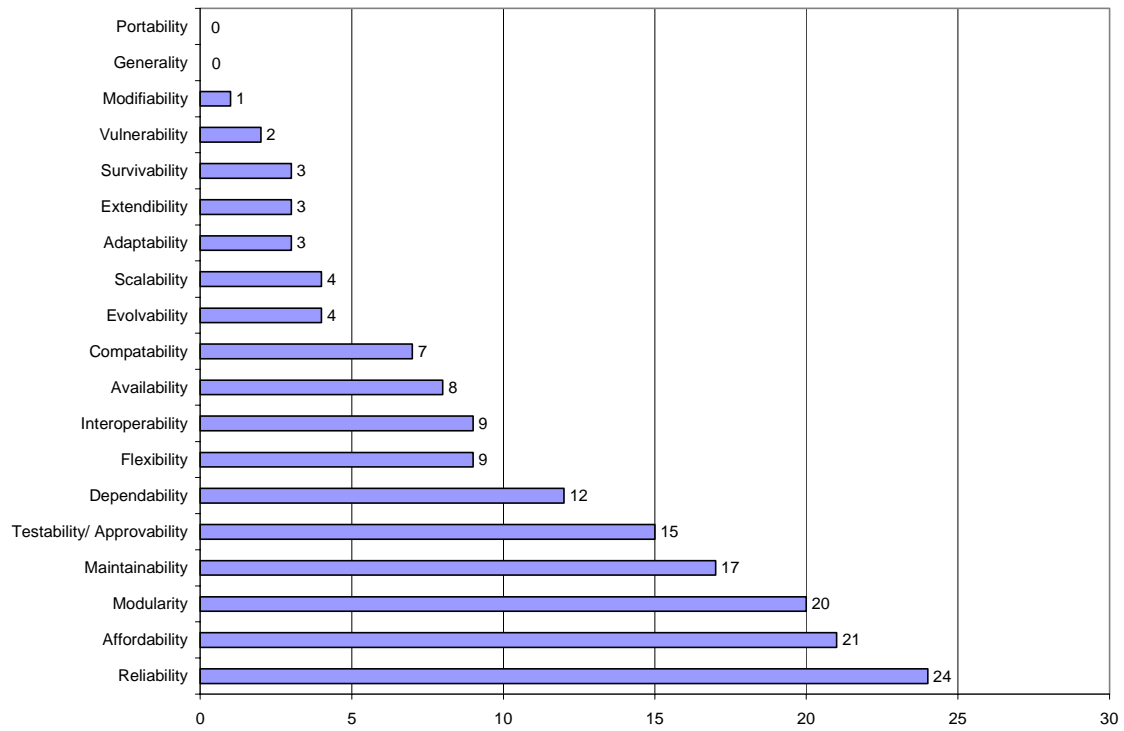
The final list of 20 UIT functions considered further included:

- Adaptability
- Affordability
- Availability
- Compatibility
- Dependability
- Extendibility
- Evolvability
- Flexibility
- Generality
- Interoperability
- Maintainability
- Modifiability
- Modularity
- Portability
- Redundancy
- Reliability
- Scalability
- Survivability
- Testability/ Approvability
- Vulnerability

Testability, not listed on the original list, was defined as the ability of the UIT to be tested using industry/utility standard test equipment. A standardized interface for test equipment to “plug” into, for example, was cited as being necessary, and the unit should readily offer information on values such as voltage and frequency setpoints.

Voting followed the development of this list, in which participants were given nine dots and asked to place as many or as few of those nine dots beside the features they considered most important for inclusion in a UIT. Results of the voting are shown graphically in Figure 3.

## Defining the UIT: Participant Discussion



**Figure 3. UIT Features Voting Results and Ranking**

## CURRENT PRACTICE WITH PACKAGED SYSTEMS

### ***Presentations***

The second session began with the following presentations:

*James M. Daley, PE, ASCO Power Technologies*, presented on “www and Facility Electric Power Management.”<sup>5</sup> He indicated that important issues to consider for this topic are:

- Electric power source and use profiles
- The electric power grid
- Prime mover/ generator control
- Control at the point of interconnection
- Relay schemes

Key conclusions included:

- Interconnection is readily achievable
- Responsive control strategies
- Adequate protection
- Interconnection can add to grid reliability

He noted that the costs of interconnection have been made more accessible through the development and use of cost effective control strategies that utilize the World Wide Web communications environment.

*Robert D. Hartzel, PE, Cutler-Hammer Inc.*, followed with a presentation entitled “Associated Barriers to Distributed Generation.” Mr. Hartzel’s discussion covered key DER system topics including:

- System coordination issues
- Present day UIT system issues
- Power quality concerns
- Utility/ regulating body paradigm shift

He indicated that:

- If site-by-site studies are undesirable, studies can be carried out by unit size range, but there will be a cost penalty.
- Present day UIT system have a lower cost than traditional systems, but also can have higher levels of complexity.
- To counter this, plug & play capabilities will be important.
- He noted that currently there is little incentive, if any at all, for utilities to use DER.
- A major utility concern is that distribution systems are not designed for bi-directional power flow.

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<sup>5</sup> Presentations from this session are available in Appendix A.

## Current Practice with Packaged Systems

*Paul E. Sheaffer, Resource Dynamics Corporation*, concluded this session with his presentation, “Overview of Currently Available UIT Systems.” Mr. Sheaffer’s presentation covered the topics of:

- The interconnection system
- The Universal Interconnection Technology Concept
- Current UIT-like offerings

He noted, especially:

- The possible components included in an interconnection system.
- The potential size of the U.S. DER interconnection market, both for new and retrofit systems, is substantial.
- The currently-available UIT-like systems are divided into traditional non-inverter based and inverter based systems. Systems built into the DER unit were also discussed.
- A table of currently available UIT-like systems was presented.

Questions and comments from the participants made in response to these presentations included:

- There was considerable interest in defining the costs of retrofitting an existing DER installation for interconnection.
- A comment was made about the need to consider existing “UIT-like” systems that are built into the DER unit and how they might be part of the UIT development process.
- Guaranteeing reliability and a company’s reputation arises as an issue when placing one company’s UIT system in another company’s DER unit.

## **White Papers**

The related White papers follow, and the Presentations are included in Appendix A.



**James M. Daley, PE, ASCO Power Technologies, “www and Facility Electric Power Management.”**

## **www and Facility Electric Power Management**

James M. Daley, PE, CCP  
Division Engineer  
ASCO Power Technologies, LP

### **Abstract**

Managing the use of electrical energy is a prerequisite to cost effective business performance. Utility deregulation has created opportunities for the facility manager to reduce the cost of electricity. Not the least of which, is the strategic use of installed generation capacity, emergency and standby power systems. The **World Wide Web** provides commerce and industry with a whole new dimension in conducting business. This paper explores the impact that the **www** can and has had on orchestrating the cost effective dispatch of alternate electric energy strategies.

### **Introduction**

“eBay.com”, “priceline.com” and others have brought the public to a new level of awareness of the Internet. Of course, engineering, science and business have been exercising computer capabilities to their limits for decades. Microsoft asks the question “Where do you want to go today?” Accenture advertises “Now it gets interesting.” That last, is probably the most telling of all. With the availability of the World Wide Web, imagination is truly the only impediment limiting departures from the common day practice.

There is a certainty! The cost of electricity is increasing. The means to control that cost is to let it operate in the market place as a commodity. However, the shift from a regulated to a non-regulated industry can have some serious short-term ramifications, as the course is traveled to a free market electrical environment.

Proliferation of the www and micro-processor based products has had a burgeoning effect on the demand for electricity. Electric demand in some geographic areas has absolutely exploded. The expansion of electric generation in some of these areas has not kept pace with the growth in demand. As a result, what was a generation safety margin became the source to carry this new demand. Thus, when demand growth in neighboring areas or natural occurrences, i.e. lack of rainfall in hydroelectric regions, reduced available generation capacity, some areas were left with little to no reserve capacity. This resulted in rolling blackouts during high demand peaks. Consequently, businesses were forced to close or find other means to meet their needs. Those businesses that had emergency or standby power systems were able to mitigate the impact of reduced availability of electric energy to some degree.

It has been estimated that there are currently “...over 60,000 MW of distributed generation installed in North America in the form of reciprocating engines and gas turbines...”<sup>6</sup> The strategic dispatch of these resources will play a key role in maintaining business continuity and control over end user cost of electricity as deregulation of the electric utility system moves forward.

### **End-User Electric Load Demand**

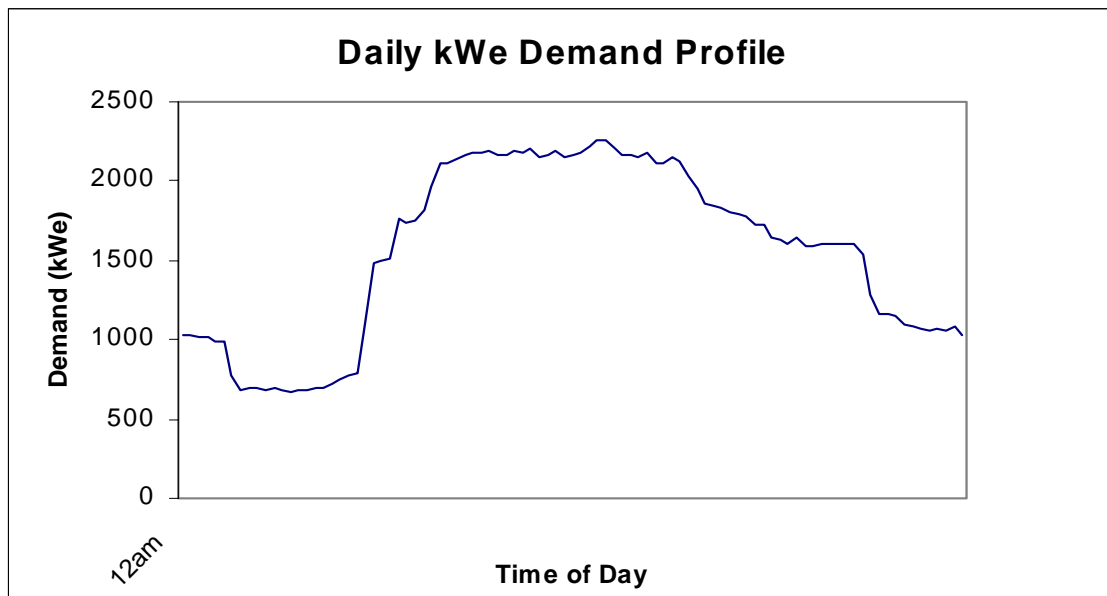
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<sup>6</sup> Little, Arthur D., Distributed Generation: System Interfaces; Arthur D. Little, Acorn Park, Cambridge, MA 02140, ©1999

The news media has been rife with stories and reports of excessive demands for electricity that are stressing the ability of the installed infrastructure. There are two prevalent aspects of this problem. The first is generation capacity and the second is the ability to deliver the energy to the point of need. In its simplest form, deregulation of the electric utility system seeks to separate the generation of electricity from the delivery of that commodity. In essence, under deregulation, generation is no longer regulated. However, the transmission and distribution system remains under regulation. (There is no intent herein to debate the merits of these issues. The writer accepts this fact and examines alternatives under these conditions.) To understand the generation/transmission-distribution issues, one needs to understand the driving forces.

**Figure 1** is a plot of the daily electric demand profile of a light industrial facility. Note that as the working day begins, the demand for electricity increases. This demand is the rate at which electricity is used. **Figure 1** is a plot of the average demand for electricity in 15-minute intervals throughout the day. The sharp increase in the beginning of the day shows how the facility turns on. Office HVAC and production machinery is turned on just before the employees arrive and remain on until the facility closes down at the end of the day. Note that the reduction in demand at the end of the day is in distinct steps that differ from turn on. This is due to the staggered departures of employees at the end of the day. Note also that the peak demand is more than 3 times the quiescent demand of the early morning hours. The shape of this demand curve is quite typical for light industrial, commercial and office facilities.

The demand curve for the aggregate residential loads differs in that it peaks twice during the day. The first peak occurs in the early morning. The second peak occurs in the late afternoon to early evening. Intuitively, this is logical. The people who use the electricity are at home in the morning and evening and at work during the day.

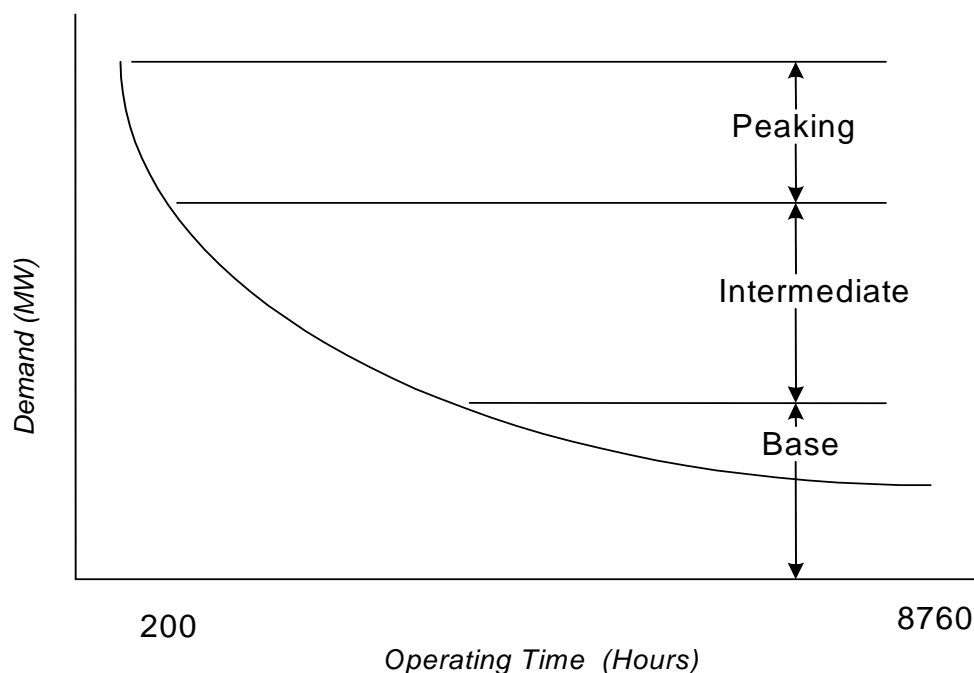


*Figure 1. Typical Electric Load Demand Profile for a Light Industrial Facility*

The actual peaks of these demands are affected by a third factor. In areas where winter heating is the peak season, the maximum demand will occur in winter months and will be a function of the severity of the weather. In areas where summer cooling is the peak season, the maximum demand

will occur in summer months and will be a function of the severity of the weather. From season to season there will be considerable variations in the peak demand. From year to year there will also be considerable variations in the peak demand.

**Generation and Delivery of Electricity** There are two distinct concerns dealing with the availability of electricity at the desired point of use. Neither the generator nor the deliverer of electricity has any significant influence over where users choose to build their facilities.



*Figure 2. Generation yearly operating hours*

Being regulated, the transmission/ distribution system must provide the infrastructure to deliver electricity on demand. That is not to say that the end user is free of any costs to install infrastructure. Because no one wants to live next to a generation station, generation is typically remote from the point of use. Because demand varies throughout the day and year, generation capacity varies. Finally, because it is physically cost prohibitive to build one large generator to carry the peak demand, several generators are typically networked to provide power on a common power grid. Economies of scale and cost effectiveness of different generation techniques are commonly mixed to provide for a best cost scenario. For example, nuclear, coal and/or hydro-power may form the base load generation for a power grid. Generation consisting of gas fired turbines with combined cycle steam generation will form the intermediate generation and gas fired packaged peaking turbines will form the peak demand response generation. Commodity cost, electricity, is lowest for the base generation case and highest for the peaking. Affecting this commodity cost is the cost recovery of infrastructure to generate. What does that mean? **Figure 2** is an approximated plot of generation operating hours during the year. The plot illustrates that base generation operates at rated capacity for most of the year. Intermediate plants operate at rated capacity for up to 4000 or so hours per year. Peaking plants operate at capacity for up to about 200 hours per year. The cost for infrastructure of peaking plants is amortized over 200 or so yearly hours of operation. It is thus demonstrated why electricity from peaking units costs dollars per kWh while it costs cents per kWh from base generation plants. A representation of those costs is shown in **Figure 3**. This terse review establishes why those peak stress periods are so

costly.

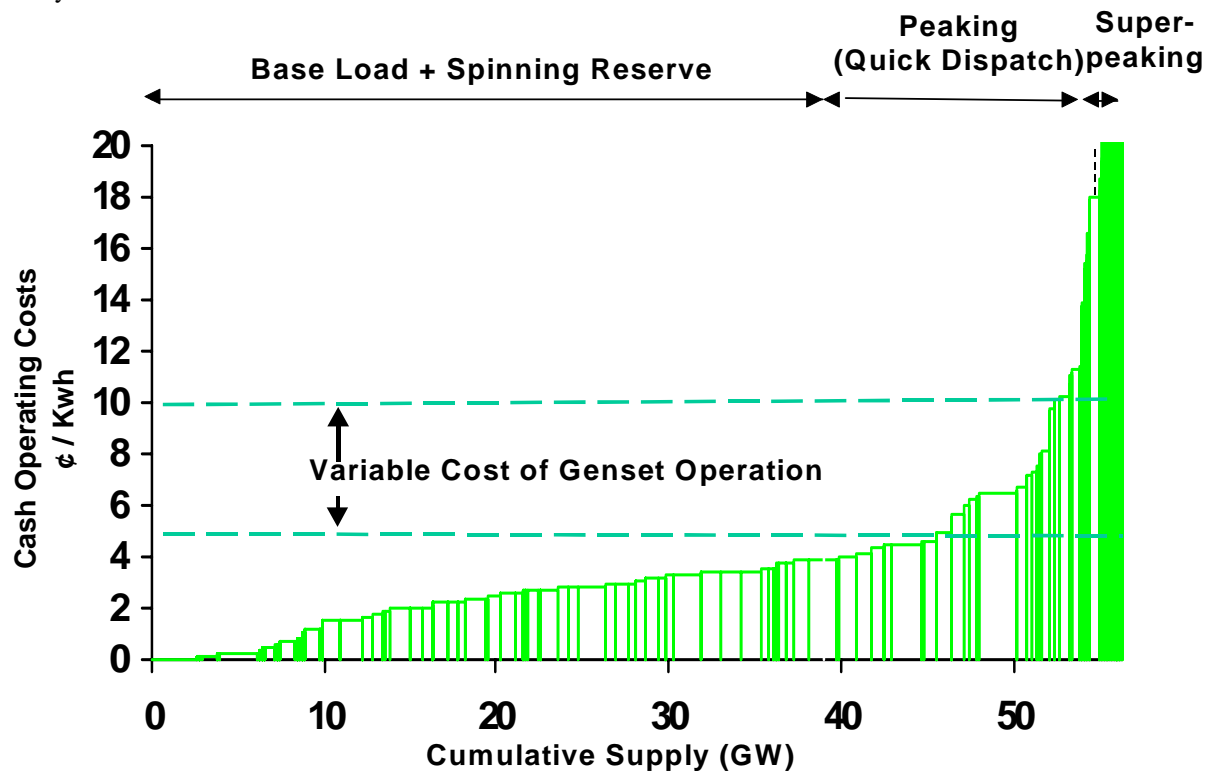


Figure 3.

### On-site Generation

The National Electrical Code, NFPA 70, Art. 700, 701 and 702 address the provisions for installation and operation of Emergency, Legally Required and Optional Standby power systems. Each of these systems are independent and capable of providing power to selected loads when the utility derived power source is inadequate. This code allows the use of these systems for peak shaving, “...The alternate power source shall be permitted to be used for peak load shaving...”<sup>7</sup> This first appeared in the NEC in the 1970’s as a result of the energy crisis at that time.

As a result of major power outages in the ‘60s’ and ‘70s’ on-site generation capability expanded. Fueling this expansion was the increasing dependence on real time data processing and computerization of business practices. As a result, there is a tremendous installed base of generation fully capable of being brought into service to address the rolling blackout issue. As a matter of necessity, these power systems are designed to start automatically and carry their respective loads whenever the utility derived voltage supply to their respective loads becomes unacceptable. So, when there is a rolling blackout on a distribution radial feeding a facility where on-site generation is installed, the protected loads will be restored to power from the alternate source automatically. This will occur in less than 10 seconds from the time the utility power is cut off. In code mandated installations, these systems must be periodically, typically monthly, exercised to confirm their availability. The reliability of these systems is very high. With over 500,000 transfer switches installed and judging by the frequency of service calls and warranty service one manufacturer experiences, reliability of these systems is well in excess of several 9’s.

<sup>7</sup> Art. 700-5(b), National Electrical Code, NFPA 70, National Fire Protection Association, Inc. One Batterymarch Road, Quincy, MA 02269, C1998

These systems are installed to manage risk. As such, they are somewhat of an insurance investment. How does one determine the ROI (Return On Investment) on an insurance investment? Given the existence of these systems and the allowance to use them for peak shaving, encouraged by incentives to reduce demand for short periods, additional investment in these facilities so that they can be brought into service during peaking periods is a viable consideration. The issue is what investment derives the best cost/benefit.

### **The Starting Point**

The hypothesis is multifaceted:

1. The cost of the on-site generation is a sunk cost
2. Use of the on-site generation for peaking is self funding and yields a net positive cash flow
3. Costs to take advantage of the peaking capability of installed generation can be recovered within 3 years
4. Automation of the process is achievable with minor peripheral additions
5. Performance can be captured and verified.

The on-site power system will come in many shapes, sizes and configurations. There is a commonality however that makes it possible to resolve this multitude of configurations into three basic system types. They are:

1. Single engine single load, **Figure 4(a).**
2. Single engine multiple loads, **Figure 4(b).**
3. Multiple engines on a common bus, **Figure 5.**
- 4.

These figures illustrate the breadth of on-site generation as installed for alternate power purposes. Taking advantage of this installed capacity for peaking will require:

- a means to dispatch
- load control
- verification
- operating summary
- integration with net neutral staffing.

Dispatching requires that the on-site generation be capable of being started and stopped on command. This command can issue from an in house controller or be responsive to an external signal. Deregulation of the electric utility system has spurred the growth of generation aggregators. These are businesses that make arrangements with the owners of on-site generation to pool and broker on-site resources. They will aggregate several of these resources so as to achieve at least the minimum required generation capacity to permit membership in the controlling PX or ISO (Power Exchange, Independent System Operator). Typically, these require a signed contract between the PX/ISO and aggregator. The aggregator will typically require that the on-site power system be made available to him for remote dispatch. When needed, the aggregator will initiate the start and operation of the on-site resource. The agreement will settle on a capacity from the host facility. It makes no difference to the electric grid whether the demand reduction is due to load disconnect or on-site power generation, load transfer. The net effect on the demand on the grid is the same. However, the host facility is keenly interested in maintaining operations. Therefore, load disconnect is not typically a viable option.

Additionally, load transfer brings with it, the concern for operational transparency. Simply stated, regardless of the power source or switching, the load should not experience any transient conditions that would negatively impact its operation. Load transfer strategies are many and varied. Some of the variations are due to the unique nature of a load; some are a result of the

unique approach a manufacturer may choose in product design; some of these to the benefit and others to the detriment of power continuity to the load. For the curious reader, a treatise on the subject of load transfer strategies can be found in a paper that was presented at an IEEE IAS Conference in the Spring of 1998.<sup>8</sup>

Given the typical control strategy of load transfer, all that would typically be required to initiate peaking load transfer would be an initiate signal to simulate the loss of utility derived power. This signal, delivered to the transfer switch, would cause an operating scenario exactly the same as would be initiated for periodic testing to meet code availability requirements. If the transfer strategy is suitable for system test requirements, it is suitable for peaking requirements. To determine successful operation, an auxiliary contact confirming that the load is connected to the on-site generator is all that would be required. Thus, the initiation and confirmation of operation are readily achieved. What hardware is required? For the case of the single load/single generator, a simple modem and controller would suffice. If the transfer is one of the more current product

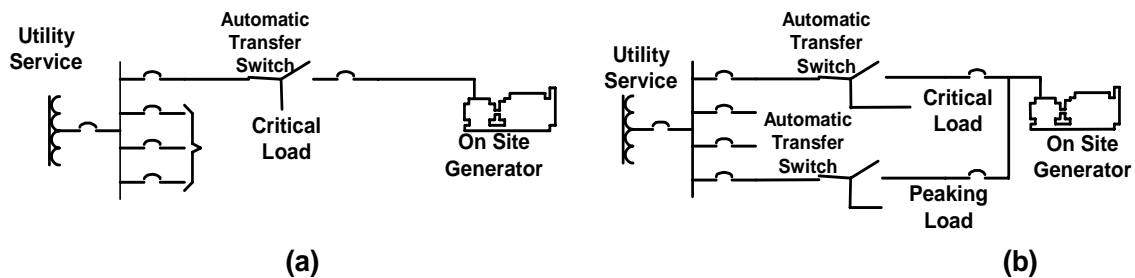


Figure 4. Simple on-site alternate power systems.

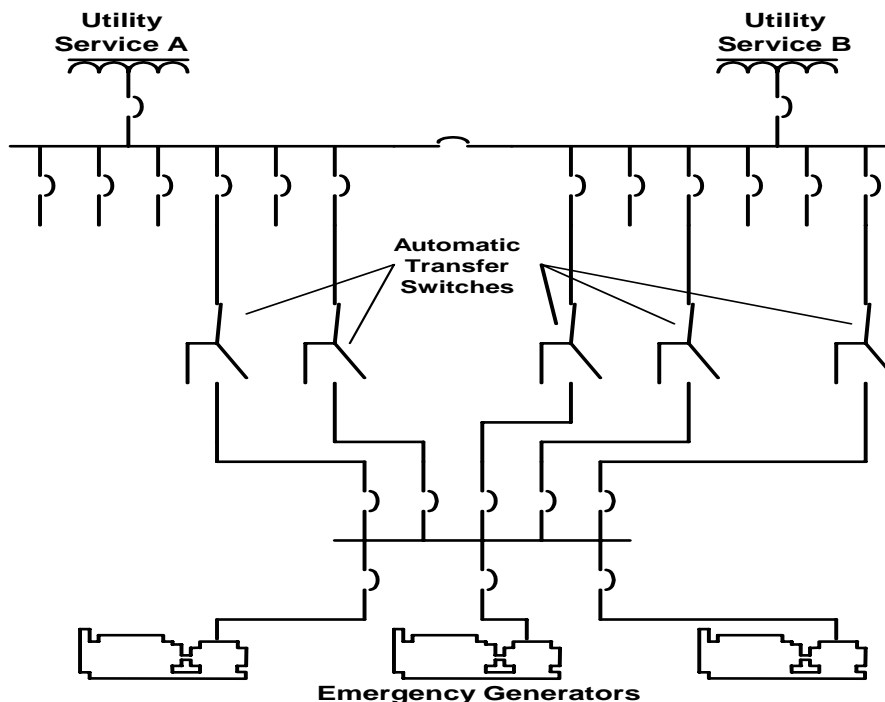


Figure 5. Multiple generator alternate power source.

<sup>8</sup> Daley, James M.; Load Transfer Strategies for Machine and Other Inrush Loads; IEEE Transactions on Industry Applications, VOL. 34, No. 6, November/December 1998; IEEE Operations Center, 445 Hose

designs, it may already have communications and control capability built in. If not, the equipment required to provide this is relatively inexpensive.

Suppose, for whatever reason, the end user has an issue with using the critical load for peak demand reduction, (usually an emotional issue), it is likely that the savings from peak shaving will finance the cost of a second load transfer circuit specifically dedicated to peaking. Such a circuit is shown in **Figure 4(b)**. Initiation and control would be as just described.

Where the on-site generation is comprised of two or more generator sets paralleled on a common bus, considerable flexibility and latitude is available. Typically, paralleling switchgear contains a programmable logic control system that is readily adaptable to expand the logic to accommodate peaking power scenarios. In this case, the initiate signal could be sent to the system controller or ATSE (Automatic Transfer Switch Equipment) which ever provides the most cost effective scenario. Whatever the configuration, load control is typically cost effectively achievable.

When called to operate, an aggregator will be required to confirm to the PX/ISO that he has provided the amount of contracted resource. Therefore, the aggregator will require that the host facility provide a means to measure and record the energy produced by the on-site generator during the required operating period. This verification will be a prerequisite for capacity payment. It should be kept in mind that the call for operation will be during those 200 yearly hours when the cost of other kWh is in the \$\$/kWh range.

In response to this need, there are many means to record and communicate energy flow in an electric circuit. The site aggregator will likely have a predetermined arrangement for data collection and recording. The ideal data record will date and time stamp operations. In addition, it will record the kWh and demand on the on-site generation and maybe even those data on the utility derived service for the same time frame. The date and time stamped record of on-site generated kWh and kW demand would form the minimum set of data to confirm production of electricity coincident with the PX/ISO declared stress period. These records would confirm the operating summary.

What has been described thus far has not mentioned the need for increased staffing to provide on-site generation availability. In fact, the proliferation of data communications and software configurable equipment makes it all but a certainty that additional staffing will not be required. Here is where the internet comes into the picture. It is useful to explore the possibilities.

### **Single Generator/Single Load**

Where the transfer switch is an open transition double throw device, only the load on that switch can be removed from the utility derived service. Therefore, load reduction will only equal the real time load (active load) served by that ATSE. Where the load transfer switch is either a closed transition or delayed transition transfer device that can be used as a paralleling device, the potential to take full advantage of the generator kW rating exists. Assume the latter case.<sup>9</sup> Figure 6 represents a single load/single generator application where the transfer switch is capable of parallel operation of the generator with the utility derived service. To adapt this installed resource to distributed generation service, one would add protective and data collecting means to the utility and generator derived feeders. Additionally, a controller would be added to orchestrate the operation on command. As **Figure 6** illustrates, a power manager has been added to the utility

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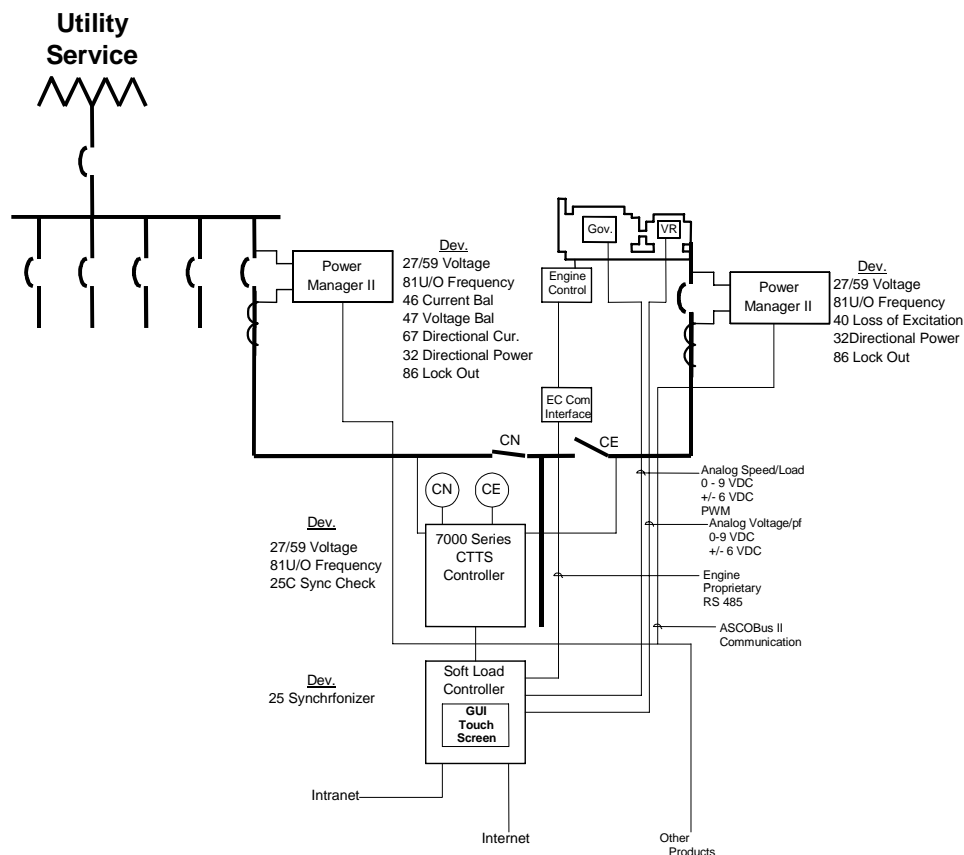
Lane, Piscataway, NJ 08855-1331

<sup>9</sup> Note: The writer suggests that the generator be run at 80% of its standby rating when operated in the peaking mode.

and generator feeders and the Soft Load Controller, SLC, has been added. There are two important points to be made here. The power managers include protective relaying functions whose principle role is to separate the power sources immediately on the occurrence of a disturbance.

Should any failure occur in the control scenario, the installed ATSE reverts to being a transfer switch and operation for distributed generation is terminated. The ATSE can be configured to keep the load on the generator until the need for peaking is terminated. In that event, the load reduction is equal to the active load on the ATSE circuit.

As **Figure 6** indicates, the soft load controller can be accessed through the Internet. Obviously, the control will have password protection to prevent unauthorized access. It is useful to go through a typical operation. The operation begins with a remote terminal accessing the SLC to initiate a peaking operation. On initiation, the engine generator is started and the SLC controls generator frequency and voltage to match the utility derived source. The SLC then brings the generator into synchronism and initiates closure of the CE contacts. Once closed, the SLC causes the EG set to assume load. There are two modes of operation available. If islanding is selected, the EG set will take on load until the load remaining on the utility derived service is reduced to a low preset value. At that point, CN will open leaving the load on the EG set. If maintained



**Figure 6. Global representation of the Soft Load Transfer control and communications strategy.**

parallel operation is selected, the EG set will take on load to some predetermined value. That value will not exceed the rating of the feeder circuit. However, it can be a value that could have a



positive or negative power flow from the utility derived feeder circuit. In the maintained parallel operating mode, EG set base loading, the EG set output increases to a value. If the load of the ATSE exceeds that value, then the utility derived circuit will provide the additional power required by the load. If the load of the ATSE is less than that value, then the excess power will flow into the switchgear bus to which the utility derived feeder is connected. Given that the load of the facility will exceed the EG set output, while none of this excess power will flow into the grid, it will serve to further reduce the facility demand on the grid. Thus the major advantage of the base load operation is revealed. Regardless of the real time power demand of the ATSE load, a fixed, maximized facility demand reduction is made available for DR (Distributed Resource) service. This operating mode has the maximum return on the incremental invested capital to achieve DR service. The incremental capital investment to achieve this operation can be in the \$10 k to \$20 k range.

**Multiple Loads/Multiple Generators** Increasing need for power reliability has caused many facilities to install multiple EG sets to meet the expanded standby power needs of important loads. **Figure 7** provides an illustrative example of such a facility. Obviously, power systems of this size provide major opportunities for peaking operation. In the system shown, the installed standby power infrastructure can be brought into operation for peaking either by transferring the loads to the on-site power bus or by adding a circuit for paralleling the on-site power bus with the utility derived power bus. The advantage of parallel operation is that it provides for full use of the EG set capacity. The advantage of load transfer is that it minimizes the incremental investment to make the on-site power system available for peaking service. Load transfer peaking will require power managers with protective functions as previously discussed and an SLC.

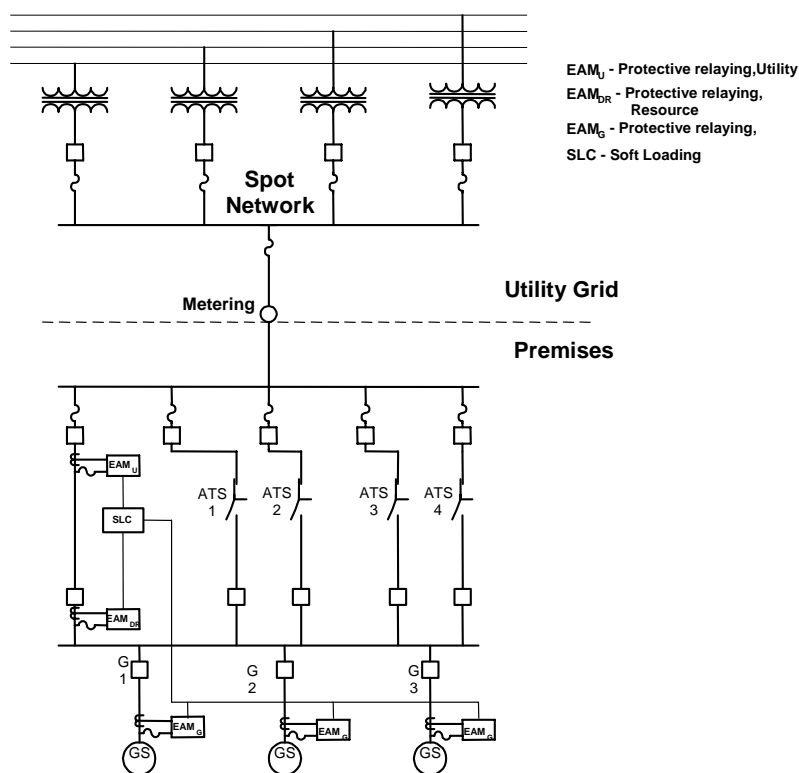


Figure 7. Multiple generators/multiple

## Net Access

Referring back to **Figure 6**, note that the SLC has communications capability for intra or internet access. Where the SLC operates in a windows environment, there exists the opportunity to provide icon interface that makes operator use less foreboding. Such operating environments will typically provide adaptable formats. Communications are adaptable to a variety of data processing needs.

From the facility manager's point of view, the computer sitting on his desk can be booted with the necessary software that enables the communications in a windows environment that would allow him to tailor the performance to meet his needs. He may wish to be able to initiate the operation at will, from his computer. In this case, using his password access, he could:

- Call on the generator to start, synchronize, parallel and take on load
- Call on the generator to start and initiate load transfer
- Vary the load to meet the real time need
- Structure an operating report
- Structure a real time status report
- Archive operating data
- Accumulate trending reports
- Make the system available to an aggregator
- Toggle the operating scenario between islanding and base load.

Since most facility managers are already familiar with the computer windows operating environment, tailoring the system configurations to site specific conditions would be a relatively painless task. As experience grows, increased confidence will enable the manager to finesse the operation so to achieve the optimum cost advantage of the system enhancements. The real issue is keeping the incremental cost of providing this flexibility low enough to provide an acceptable ROI.

Where on-site generation has been contracted to aggregators, they can directly access the facility in a similar manner through the Internet. Operating and reporting scenarios can be tailored to meet the needs. Orders of hierarchy can be established through password privileges to restrict the scope of flexibility at various levels. The facility manager can therefore restrict what the aggregator is permitted to do with the on-site generation system.

## Summary

Modern on-site alternate power systems can be retrofitted and expanded to provide an alternative to the high cost of on peak power. The costs for these enhancements have been significantly reduced as a result of the availability of cost effective control strategies that take advantage of the World Wide Web communications environment. One can expect a reasonable ROI on the added infrastructure to take advantage of the sunk cost of installed alternate power systems.

**Robert D. Hartzel, PE, Cutler-Hammer Inc., “Associated Barriers to Distributed Generation.”**

**Universal Interconnection Technology  
Technology Roadmap Workshop**

**Associated Barriers to Distributed Generation**

**Ronald D Hartzel, PE**  
Engineering Manager, Generation Systems  
Eaton Corporation  
Cutler-Hammer Inc.  
Beaver, PA

**1 Introduction**

There are many issues that affect the successful implementation of Distributed Generation from both the customer and local utility perspective. The issues can be separated into four major categories.

- System Coordination Issues
- Present Day Universal Interconnection Technology (UIT) Systems
- Power Quality Concerns
- Utility/Regulating Body Paradigm Shift

**2 System Coordination Issues**

Many customers do not understand the importance of addressing system coordination issues before installing Distributed Generation (DG) systems. If a system is not properly coordinated it could result in equipment damage due to a severe fault current condition or unplanned outages due to improper system coordination.

**2.1 Fault Current Considerations**

Currently each site must be analyzed by a qualified engineer to determine the magnitude of the worst-case fault current condition. The engineer must develop a one line diagram and write a sequence of operations on how the sites DG will function. The consultant must contact the local utility and request the available fault current contribution for the site in question. Finally, the engineer must use the fault current contributions from the utility and DG, one line diagram, and sequence of events to determine the interruption rating of the UIT equipment. Another consideration is when the DG is operated in parallel with the utility; this will increase the required interruption rating of UIT equipment. The magnitude of the effect will depend on the type of DG used.

Most consultants use the conservative approach and assume infinite bus conditions in conjunction with the impedance of the utility transformer to determine the maximum fault current available to the site from the utility source. This is a nice general approach; however, the equipment may be oversized and more expensive than what was really required.

This is time consuming and adds cost to the implementation of DG. A possible alternative would be to conduct a comprehensive study of the US electric power system to determine what the worst-case available currents are throughout the US. Then, analyze the data to determine if the data follows some type of probability distribution. The study may reveal that at 70% of the sites the equipment can be rated 65kA. If the desire is to cover 90% of the sites then the equipment may need to be rated 100kA and if a really conservative approach is used of 100%, then the equipment may need to be rated 200kA. If this occurs, then analyze the data to see if there are any common parameters such as site voltage level, primary transformer size, primary transformer impedance, primary transformer voltage level, feeder size or other. The study would need to be published and endorsed by all utilities, so that all DG users throughout the USA can apply it.

## **2.2 Proper Coordination**

In addition to determining the interruption rating of the UIT equipment, the consulting engineer must determine all of the protective settings. This can be done by hand or by using available software packages. The engineer must determine the breaker trip unit settings, which include long, short, instantaneous and ground fault settings. In addition, the protective relay trip settings must be determined for both the utility and the DG sources. The alarm settings must be determined so that the maintenance personnel have enough time to react to system disturbances before they become a trip condition. At this time, there is no means of short cutting this work.

## **3 Present Day UIT System Issues**

There are many advantages to the new Universal Interconnection systems currently in the market. Over the past few years new embedded controllers have entered the market. These new controllers consolidated many functions, which required separate black boxes to perform discrete operations. Also, these separate boxes required many redundant point-to-point wiring terminations. Today many of these connections have been replaced by integral logic in one controller. All external inputs are wired to the embedded controller with the rest of the “connections” for different functions performed in the software. This has increased the functionality of the new systems and reduced the chance for wiring errors, decreased testing and commissioning times, and reduced overall system costs. This has lead to lower installed costs, which in turn have lowered the breakeven point for implementation of DG at many more sites.

There are a few disadvantages to these new systems. They are more complex and require a higher caliber startup engineer than the market place is accustomed to providing. Another issue is the varying degree of computer skills of the customer’s maintenance personnel. The smallest issue could result in a significant amount of time troubleshooting a trivial issue.

While most customers have a desire to save money and/or explore the possibility of developing a second source of revenue, many do not understand DG. They are not knowledgeable about the different forms of DG, associated cost with each, system design requirements, or who at the local utility should be contacted to determine all requirements and available programs.

Solutions to these issues would be to increase plug and play capabilities. This would include developing menu driven software for UIT systems that work with prime movers to allow quick selection of Governors, voltage regulators, and prime movers. There should be defaults for all settable parameters that get the commissioning engineer close to stable system operation. Another alternative may be to add the governor and voltage regulator functions to the UIT embedded controller.

There needs to be a user friendly on-board software assistant that can review parameters and suggest appropriate changes for the commissioning engineer. In addition, the software must provide assistance to the site maintenance staff so that troubleshooting time can be minimized.

Educational material needs to be created that informs customers about DG with both positive and negative examples. The material needs to discuss what programs are available, different forms of peak shaving, associated pay back analysis, questions to ask the local utility provider and a review of the applications of various types of DG. After this information has been developed a vehicle is required to disseminate the information to interested parties. It could be as simple as putting the information on every state web site in multiple places or links to get interested customers to the right place.

## **4 Power Quality Concerns**

There are two main issues of concern that affect electrical system power quality. They are Harmonics and Ferroresonance. Harmonics are becoming a more frequent issue with the increased use of inverter technology. Many harmonic issues are caused by the type of loads being served. One type of load that generates harmonics is variable speed drives. They can be purchased with different quality inverters (i.e. 6, 12 or 18 pulse inverters) that produce different levels of harmonics.

### **4.1 Harmonics**

An issue that is often overlooked by customers purchasing a variable speed drive is what the harmonics content is when connected to the utility, DG or both (parallel operation). The higher the impedance of the source, the worse the affect of harmonics on the system.

For example, consider a customer site that contains a synchronous generator (15% impedance) as its DG source and a utility source (5% transformer). The site contains variable speed drives to operate pumps. The site can be operated on utility only, Generator only, or both in parallel. On utility only the total Harmonic Distortion (THD) is 2.3%. When on generator only the THD is 5.7%, but with both in parallel, the source impedance is reduced to 3.75% and the THD is reduced to 1.75%

The issue is that THD can cause the UIT system to misoperate if the levels are too severe, but implementation of DG is still positive from the utility perspective. If harmonics levels cause too much disturbance they could lead to flicker problems at other customer sites. Many times flicker problems are related to large electrical loads being switched off and on quickly like electric arc furnaces.

Some possible solutions would be to develop customer incentive programs. These programs should encourage customers to use equipment that produces low harmonics. Again, educational literature is needed that explains the issues associated with harmonics and how source impedance affects THD levels.

### **4.2 Ferroresonance**

There are two types of ferroresonance, both produce sustained over voltages and core saturation. Saturation causes stray flux to be carried in the tank steel, which is a high-resistance short circuit by design. The losses from this condition could cause enough heat to raise the transformer oil to damaging levels. Ferronesonance can occur when a circuit with sufficient shunt capacitance

energizes a lightly loaded transformer. Transformers at 14.4kV and above have enough internal shunt capacitance to produce ferroresonance on their own. This issue will need to be examined if DG is to be used to serve peak power requirements and/or create intentional islands.

## **5 Utility/Regulating Body Paradigm Shift**

Currently, there is no incentive for utilities to use DG to offset Transmission and Distribution costs. Since utilities have separated into Distribution, Transmission, and Generation entities, their portfolios of operation are limited. For example, a distribution only utility is not permitted to own or dispatch generation assets; however, they are obligated to serve their customers. So, the utility will build transmission and distribution assets based on old paradigms and not consider using DG.

Possible Solutions to these issues would be to determine who should be given incentives to use DG. Maybe distribution type utilities should be allowed to negotiate contracts with DG customers and dispatch their generation resources in order to defer construction of new transmission lines and minimize distribution cost. Maybe the value from this type of approach should be split between the utility and their customers. Regulations should be changed to allow the utilities to have higher returns if they actively use DG to control system costs.

### **5.1 Distribution Utility Issues**

The present distribution system in the United States was not designed for bi-directional power flow. Thus all of the stability and power flow models are based on having unidirectional power flow. The operating procedures for utilities requires them to supply 100% of their load requirements with enough safety margin equal to the largest generating resource, otherwise known as spinning reserve.

Possible solutions would be to develop bi-directional distribution systems to allow power flow from DG customer sites. This could include installing additional synchronism check relays throughout the distribution system. New stability and power models are required that would utilize DG. The new distribution system may be more costly, but transmission line costs should decrease. Also, central plant cost should decrease along with overall energy cost. Finally, new tariff structures are needed to support DG versus building traditional transmission and distribution systems.

Another issue that will need addressed is the subject of spinning reserve. Most DG units take at least a few seconds to produce rated voltage and assume load. The user systems may need to incorporate a new technology, such as online energy storage devices to ride through the periods where the DG is not producing power. Currently, there are systems available in the market place that could fill this need.

**Paul E. Sheaffer, Resource Dynamics Corporation, "Overview of Currently Available UIT Systems."**

**Overview of Currently Available UIT-Like Systems  
UIT Workshop – July 25-26, 2002**

The market for Distributed Generation (DG), or more broadly Distributed Energy Resources (DER), continues to evolve. DER units are increasingly being evaluated by residential, commercial, and industrial users as solutions for their energy needs. In addition, the DER retrofit market shows great potential. With energy market restructuring, DER units can be interconnected with the grid and standby capability can be expanded to provide peak shaving, interruptible rate, and export-to-utility functions.

Interconnecting DER to the grid can offer several benefits, which include:

- Giving the customer the flexibility to use the DER unit, the grid, or both;
- Providing the customer flexibility to take advantage of special electric rate structures;
- Taking advantage of the opportunity to export power to the Area Electric Power System (EPS), or to the power pool in deregulated markets;
- Improving overall customer reliability by providing an alternative power supply option; and
- Obtaining backup power from the EPS in the event of a DER system outage, eliminating the need for complete system redundancy.

Realization of the associated benefits of DER depends on DER's successful integration into the utility or Disco EPS distribution system operations without any negative impacts on system reliability or safety.

***The Need for a Universal Interconnection Technology***

An interconnection system is the equipment that makes up the physical link between DER and the EPS, usually the local electric grid. The interconnection system is the means by which the DER unit electrically connects to the outside electrical power system, and provides for monitoring, control, metering, and dispatch of the DER unit. In short, the interconnection devices perform the functions necessary to maintain the safety, power quality, and reliability of the EPS when DERs are connected to it.

The complexity of the interconnection system depends on the level of interaction required between the DER, the customer loads, and the EPS. Typically, complete systems that allow a DER unit to parallel with the grid include the following components, which may or may not be modular:

- Exciter control system for the generators,
- Synchronizer for the reliable transfer of power between the generators and the grid,
- Automatic transfer switch control,
- Import/export control,
- Protective relay functions including over/under frequency and voltage at the interconnection points, directional real and reactive power flow, and phase-to-phase current balance,
- Metering or net metering, depending on the tariff, and
- Remote communications capabilities to accommodate control from remote control centers (e.g., direct transfer trip, in some cases).

Different applications of DER require different levels of interconnection complexity, and most interconnection today is still performed on a site- and DER unit-specific basis. This greatly increases the cost compared with what it would be if the interconnection system were standardized. Beyond this, the lack of standardization of interconnection systems can be confusing for DER users and deter them from interconnecting with the grid.

For these reasons, there has been substantial interest recently in developing a Universal Interconnection Technology (UIT). Development of a UIT would define a standard architecture for functions to be included in the interconnection system. This standard architecture would allow both DER manufacturers and end-users to easily integrate their power systems with the area EPS.

A Universal Interconnection Technology would include at least the following functions:

- Power conversion,
- Power conditioning and quality,
- Protection functions,
- Synchronization,
- DER (both generation and/or storage) and load controls,
- Communications,
- Metering, and
- Dispatch.

Other useful features could include the ability to provide ancillary services to the distribution system and the ability to communicate back to the utility the status of the distribution system.

Underlying development of a UIT are advances in interconnection components and in integrated power electronics. Electromechanical “discrete” relays, which dominated utility interconnection, protection, and coordination for years, are being supplanted by digitally based equipment, frequently with multi-function capability. Utilities themselves are gravitating towards digital, programmable relays, raising the issues of field calibration and certification. The rise of inverter technology as an alternative to rotating power conversion technology (i.e., induction and synchronous generators) has opened the door to integrated, inverter-based protective relaying.

In summary, a modular UIT will make DER installation cheaper, quicker, more reliable, and will also provide benefits to the distribution company.

### ***Current UIT-Like Systems***

Some third-party manufacturers are assembling systems of components to build complete interconnection systems that meet some of the UIT vision. There are two types of UIT-like systems currently in development:

- *Traditional non-inverter based pre-engineered systems* that allow for synchronization and parallel operation with the grid. Often these assemblies are referred to as “switchgear”, where all the necessary components are built into either panelboards, switchboards or other suitable cabinets; and
- *Inverter based UIT-like systems* for prime movers with DC or high frequency AC output (i.e. PV systems and fuel cells). These systems can also work with standard induction and synchronous generators.



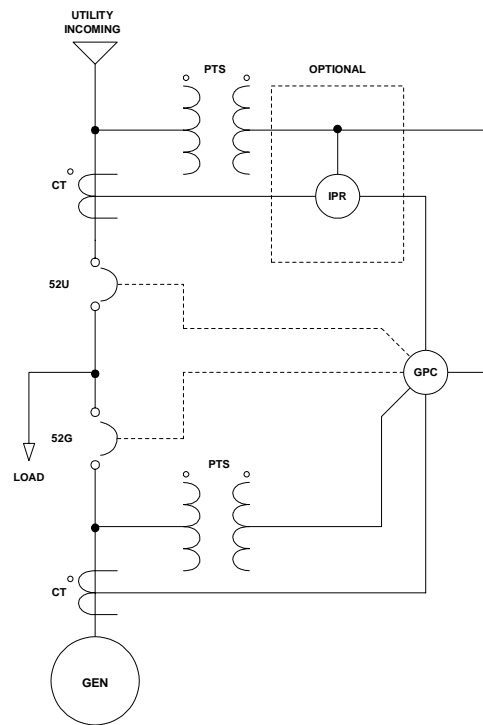
These types of interconnection systems exist for both new DER and for the retrofit of existing DER units of various manufacturers.

### **Traditional Non-inverter Based Switchgear Pre-engineered Systems**

Non-inverter based interconnection systems use microprocessor based digital controllers to synchronize and parallel DER unit operation with the grid. Often called “switchgear,” these systems are single pre-engineered structures that contain the many functions necessary for synchronization and parallel operation with the grid: operator interface, controls, protective relays, circuit breakers, and much more. Unlike inverters, these systems are generally used for DER units with more traditional AC output such as reciprocating engines, and do not provide for power conversion with inverters.

One goal is to develop switchgear that can be universally applied. Several models on the market have achieved that goal. These units focus on simplified system installation, and work with different styles or brands of generators. These UIT-like systems can be used for new DER units or to transform existing standby units to provide peak shaving, interruptible rate, and export-to-utility functions. Units are available from companies such as Detroit Diesel (SD-100), ZTR/ Shallbetter (DGX Switchgear), Kohler (PD-100), and several others.

Several switchgear systems integrate components from multiple manufacturers. For example, the ZTR/ Shallbetter DGX Switchgear uses a digital controller from Woodward, protective relaying from Schweitzer (for utility relays) and Woodward (for genset relays), and monitoring systems and software from ZTR. Kohler’s PD-100 switchgear/ paralleling switchgear system, which converts new or existing standby generators (from 20-2,000 kW) into peak shaving, prime power or electricity exporting units, uses a controller from Encorp. A single line diagram of Kohler’s unit is shown below.



**Figure 1. Switchgear Single Line Diagram (Kohler PD-100)**

## **Inverter Based Systems**

The inverter based UIT-like systems is designed for use with prime movers with DC or high frequency AC output (i.e. PV systems, wind, fuel cells, and microturbines). These technologies are expected to increase their share of total power produced in the United States and abroad, setting the stage for inverter based UIT-like systems to interface DC power sources with the grid. Microturbines, which produce high frequency AC, are well suited for use with inverter based UITs since their rectified output (i.e., DC) can be directly fed to the inverter, which then converts it to 60-Hz AC.

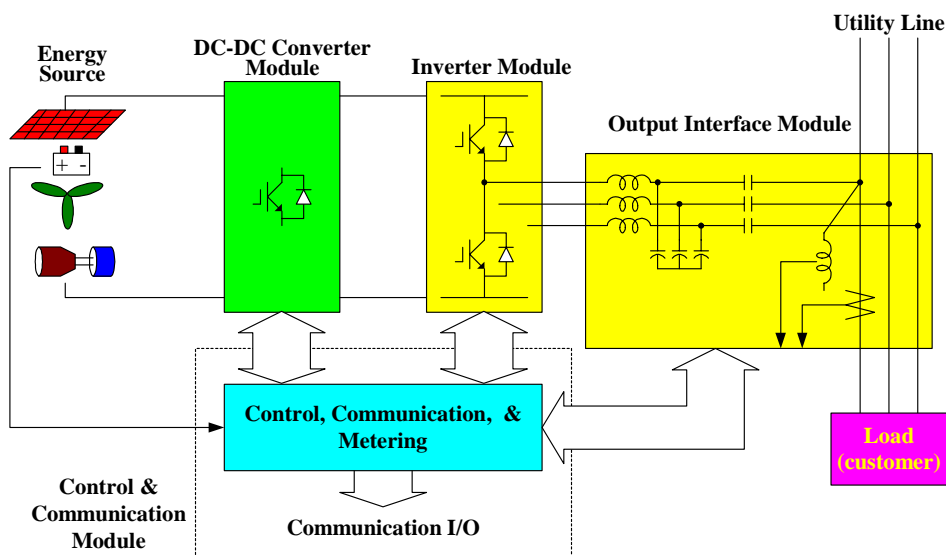
The Department of Energy, through the Oak Ridge National Laboratory, recently published a White Paper entitled “*White Paper on the Development of the Universal Inverter for Distributed Energy Resources*.” This paper outlines concepts and designs for the development of a universal inverter. The paper determines that for present-day inverters to meet the requirements of a UIT, several issues must be addressed. These include:

- Switching device ratings (and associated reliability issues),
- Transformers (and associated design limitations),
- Lower cost,
- Control limitations,
- Limitations on voltages that can be attained, and
- Creation of high levels of harmonic distortion.

In addition, DG inverters will be required to at minimum provide services such as voltage regulation, frequency regulation, and reactive power supply.

The DOE White Paper focuses on the importance of modular inverter systems. Advanced Energy Systems offers two inverter based interconnection systems, one for residential and small commercial power systems (PV and wind power) and the other for entry-level grid-tied, battery-less photovoltaic systems. These units meet UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection. Another currently available inverter based UIT-like model is Ballard’s EcoStar Power Converter, which is designed to operate with microturbines. A diagram showing the modular building blocks of an inverter based UIT system is shown below.

Inverter systems also integrate components from multiple manufacturers. AstroPower SunChoice program offers two grid-tie PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).



**Figure 2. Universal Inverter Modular Building Blocks**

In the future, inverter based interconnection systems may be applied to standard reciprocating engine gensets. Benefits include higher efficiency and lower emissions at part load. Honda currently manufactures a 3,000 watt genset whose generator produces 200 volts at 14 to 17 Hz, which is converted to 12 volts DC, and then inverted to 50 or 60 Hz AC. Honda claims a higher power quality than standard gensets.

### Current Products

Table 1 lists some of the UIT-like systems currently on the market. These systems will need time to truly obtain the goal of “universal” status; meanwhile they highlight market developments.

**Table 1. Currently Available UIT-Like Systems**

Company	Unit	Inverter	Non-Inverter	Electrical Specification
Advanced Energy Systems	MM-5000 – Grid-Connected MultiMode Power Conversion System	X		5 kVA
	GC-1000 1kW Grid-Connected Photovoltaic Inverter	X		1 kVA
AstroPower	SunChoice Program	X		8.5 kVA
Ballard	EcoStar Power Converter	X		Up to 110 kVA
Cummins Power Generation	PowerCommand Digital Paralleling Equipment		X	Up to 2,500 kVA
Detroit Diesel	Spectrum SD-100		X	Up to 2,400 kVA
Encorp	enpower-GPC powered “paralleling switchgear”		X	800-5000 amp
Fire Wind and Rain Technologies, LLC	Power Streak Inverter	X		5kVA
Kohler	PD-100 Switchgear		X	Up to 2,500 kVA
Thomson Technology	Distributed Generation Switchgear System/ GCS 2000-DG System		X	Up to 4,000 amp
Vanner Incorporated	RE Series Inverters	X		5.6 kVA
Xantrex	Grid Tie Inverters	X		Up to 125 kVA
ZTR/Shallbetter	DGX Switchgear		X	Up to 4000 amp

Details of existing manufacturer product offerings, based on manufacturer-developed product literature, are now provided.

**Advanced Energy Systems.** Advanced Energy Systems has two grid-connected inverter based systems. The *MM-5000 – Grid-Connected MultiMode Power Conversion System* is a two-stage, DC to AC grid-tied inverter designed for residential and small commercial power systems (PV and wind power). It operates in stand-alone, grid-parallel, backup generator, and multi-unit modes with simplified programming and data retrieval, flexible operating modes, and intelligent user and wiring interfaces. It offers a fully integrated, single-box solution, including a charge controller, and all switchgear, a single reprogrammable microcontroller, and complete system control. Anti-islanding technology is available for operation in grid-parallel mode, and an input ground fault protection circuit provides improved operating safety.

The *GC-1000* 1kW Grid-Connected Photovoltaic Inverter is for entry-level grid-tied, battery-less photovoltaic systems. The inverter includes a string combiner, DC and AC disconnects, and ground fault interrupt protection. An optional interactive data monitor is also available. This system meets UL 1741 and IEEE 929 requirements including anti-islanding and over/under frequency and voltage shift detection.

**AstroPower.** AstroPower's SunChoice program offers two grid-tie PV systems: the SunLine™ system and the SunUPS™, which includes emergency power (battery backup) capabilities. These systems incorporate inverters produced by AEI (GC-1000 and GC-3000 models), Xantrex (XR1500 and XR2500), and SMA (sunny boy SWR1800 and SWR 2500).

**Ballard.** Ballard's *EcoStar Power Converter* is designed to operate with microturbines, although subsequent units will be targeted at internal combustion engines, PV systems, fuel cells, wind turbines, super capacitors and flywheels. The converter provides "electric grid compatibility," anti-islanding functions, parallel operation, and communication ports and protocols for units up to 110 KVA.

**Cummins Power Generation.** The Cummins *PowerCommand Digital Paralleling Equipment* includes all monitoring, protection, governing, voltage regulation, as well as all paralleling control functions including synchronizing, load sharing, and paralleling protection plus utility paralleling functions such as import/export control, and VAR and power factor control. Their PowerCommand Network is a Windows®-based, distributed system for local or remote monitoring and control, real-time data collection, retention, and report generation on generator sets, transfer switches, paralleling controls, switchgear, and other related power generation and distribution equipment. The combined system interfaces with all leading building management systems and automation packages.

**Detroit Diesel.** The Detroit Diesel *Spectrum SD-100* works with new or existing gensets in several modes including standby power, peak shaving, interruptible rate, and export-to-utility modes. The system includes operator interface, controls, protective relay, a circuit breaker (800-4,000 Amps) for paralleling, and monitoring functions for electric systems up to 600 VAC at 60 Hz.

**Encorp.** The Encorp enpower-GPC "*paralleling switchgear*" includes control modules, protective relays and network communications capabilities in a single, microprocessor-based "gold box." The system parallels one genset with the utility in base-load, peak-shaving, import/export or zero-power-transfer mode, and can be used for new gensets or for retrofit options. The enpower-GPC supports both the Modbus® and LONWORKS® communication protocols.

**Fire Wind and Rain Technologies, LLC.** This company's *Power Streak Inverter* can be used for grid tie or standalone application.. The Power Streak 4K is the first member of the Power Streak family of inverters/battery chargers based on a versatile modular inverter subsystem. It includes everything necessary for use including the inverter, weatherproof enclosure, DC and AC disconnects, Isolated Computer interface, remotable Liquid Crystal Display, Generator Control Modes and more. and is UL 1741/IEEE 519 compliant. The Power Streak is available with several input and output options including 48 or 120V DC inputs, and 120 or 240V outputs.

**Kohler.** The *PD-100 Switchgear/ Paralleling Switchgear* system is used to turn new or existing standby generators (from 20-2,000 kW) into peak shaving, primary power or electricity exporting tools. The system includes a circuit breaker (800-4,000 Amps), touch screen monitoring, control functions (the controller is manufactured by Encorp), protective relaying, and communications; for systems up to 600 VAC at 60 Hz.

**Thomson Technology.** Thomson Technology Inc.'s *Distributed Generation Switchgear System/ GCS 2000-DG System* is used for synchronizing single or multiple generators to the utility grid. The system incorporates control logic and software programming for automatic synchronizing, soft load transfer and automatic load (kilowatt) and VAR/PF control. It can work with a variety of industry standard communications for remote monitoring, control, and data logging, and can be used with either new systems or retrofits.

**Vanner Incorporated.** Vanner makes a series of inverters, including the *RE Series*, that accepts grid or generator input. The RE Series is designed specifically for alternative energy applications, and include multiple functions, including transfer switch, automatic generator control capabilities. The inverter has a 4500 Watt continuous output and is programmable with the Inverter/Charger Remote Control.

**Xantrex Technology Inc.** Xantrex manufactures utility interactive, three-phase inverters for solar arrays, with models ranging from 5 kW to 100 kW. Multiple inverters may be paralleled for larger power installations. Functions such as over- and under-voltage and frequency protection, anti-islanding protection, automatic operation including start-up, shut-down, self-diagnosis, and fault detection are included. The Grid Tie system consists of a solar array and the grid tie inverter, which includes all components necessary to make a grid connect system installation. The Trace™ ST Series inverters include the balance of system components for ease of installation.

**ZTR.** ZTR, in partnership with Shallbetter, Inc. produces the *DGX Switchgear*, which can be used for a genset paralleled to the utility, upgrading non-automatic switchgear, or for a genset retrofit. The system combines components from several manufacturers: a digital controller (Woodward EGCP-2), protective relaying (utility: Schweitzer, genset: Woodward EGCP-2 integrated feature), and monitoring via a ZTR-Lynx monitoring and supervisory control system. The switchgear is used for units up to 15 kV.

### **Built-in Systems**

Many DER manufacturers have been either building in, or offering as an option, some of the key interconnection equipment components as part of their DER genset offerings. Some of these units, especially those incorporated into microturbines and fuel cells, have many of the same functionalities as a UIT.

In an effort to streamline the interconnection approval process, the California Energy Commission has established Type Testing and Production Testing requirements for equipment under its Rule 21 program. Systems that meet these requirements are considered to be Certified Equipment for purposes of interconnection with the distribution system. Rule 21 certification may apply to either a pre-packaged system or an assembly of components that address the necessary functions. Thus far, DER manufacturer systems are the only systems to be certified though it seems likely that UITs could benefit from this process as well.

Plug Power’s Model SU1PCM-059622 5kW stationary fuel cell system was recently certified to comply with the Rule 21 requirements. Capstone’s Model 330, 30 kW microturbine generator and Model 60, 60 kW microturbine have also been certified to Rule 21. These systems, like a UIT, contain all the components necessary for interconnection.

### ***Future UIT Functions and Features***

An issue for any UIT is its ability to provide certain functions and features. As a starting point, any UIT must provide safe interconnection with the EPS including all the necessary functions previously mentioned (power conversion, power conditioning and quality, protection functions, synchronization, DER and load controls, communications, metering, dispatch, ancillary services, and communication of the status of the distribution system) – all without harming grid reliability or power quality.

Beyond these functions there are a number of features that should exist in a UIT. Some features are listed below:

1. Adaptability

The ease with which a system satisfies differing system constraints and user needs.

2. Affordability

To have a cost which is bearable. For a UIT system, the cost of the interconnection component is a small part of the overall installed DER system cost.

3. Availability

The degree to which a system is operational and accessible when required for use.

4. Compatibility

The ability of two or more systems or components to jointly perform their required functions while sharing the same hardware or software environment.

5. Dependability

That property of a system such that reliance can justifiably be placed on the service it delivers.

6. Extendability or Expandability

The ease with which a system or component can be modified to increase its storage or functional capacity.

7. Evolvability

The ease with which a system or component can be modified to take advantage of new (internal) software or hardware technologies.

#### 8. Flexibility

The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed. For interconnection systems, the ability to adapt to:

- New types of DG prime movers,
- Emerging storage platforms,
- New applications (e.g., ancillary services),
- Diverse distribution systems,
- New communications protocols.

#### 9. Generality

The degree to which a system or component performs a broad range of functions.

#### 9. Interoperability

A system that can exchange information with and use information from other systems.

#### 10. Modularity

A modular interconnection architecture divides the interconnection system into discrete components (building blocks) each performing standard functions like the following:

- DER control,
- Power conversion,
- Voltage regulation,
- Power quality,
- Protection,
- Synchronization,
- Communications/control with load,
- Metering,
- Dispatch, and
- Area EPS communications and support.

The definitions of the modules should be generic enough to apply to both inverter and non-inverter systems, so that they have common building blocks. Not all interconnection systems will require all blocks.

#### 11. Maintainability

The ability of a system, under stated conditions of use, to be retained in, or restored to, a state in which it can perform a required function.

#### 12. Modifiability

The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined.

#### 13. Portability

The ease with which a system or component can be transferred from one hardware or software environment to another.

#### 14. Reliability

The ability of a system to perform a required function under stated conditions for a stated period of time.

15. Scalability

The ability to incrementally add functionality to a system without replacing it completely. Scalability means that an interconnection system designed for one application (e.g., peak shaving) may be “scaled up” by adding additional modules for a more complex application (e.g., utility dispatch).

16. Survivability

The degree to which essential functions are still available even though some part of the system is down.

17. Vulnerability

The degree to which a software system or component is open to unauthorized access, change, or disclosure of information and is susceptible to interference or disruption of system services.

One goal of the UIT Workshop is to review how well existing technology provides these functions and features, and where there are gaps in existing technology. In answering this, there may well be differences in the new generator and retrofit markets.



## ***Current Practice with Packaged Systems: Participant Discussion***

Utility approval plays a determining role in the success of DER interconnection with the EPS. A series of factors have combined to make utilities, in many instances, uncomfortable with or resistant to DER interconnection. Addressing utility concerns will be an important part of UIT development.. A group discussion was initiated to address these issues, and the following question was presented:

How can we design a UIT system so that utilities embrace DER?

### **Utility Adoption of DER**

*How can we design a UIT system so that utilities embrace DER?*

It was agreed by the participants that utility needs would play a role in the development of the UIT. Several functionalities were discussed which could be included in the UIT to make it and DER more attractive to utilities. First among these was universal testability. The ability to provide ancillary services, dispatchability, and aggregatability were listed as additional functions of import. The group made the following comments in this discussion:

- Utilities look for benefits from DER that can be obtained (i.e. make the utility money, solve problems) without causing headaches.
- Utility ownership of DER will increase its penetration.
- Ability to aggregate DER is important to utilities.
- Utilities will likely require a standardized way to connect with DER.
- Testability of the unit and the interconnection will increase utility comfort.
- Efforts to define common communication protocols should incorporate utilities.
- Local control will be a plus for utilities.
- As utility become more “comfortable” with DER, their acceptance of it will increase.
- A cost incentive must exist for utilities to embrace DER.
- Training utility staff in DER may need to occur before acceptance will follow.
- Safety issues must be addressed.
- DER that make the grid “smart” will be better received.
- Ancillary services (reserve) are a bonus, as is the ability of utilities to count DER towards reserve/ margin.
- DER needs to be dispatchable and provide T&D benefits.
- Utilities must first learn how to “value” DER.

Participants commented that utilities will not want to deal with many small individual DER units, a fact that makes aggregatability that much more important. A clear financial model is important when presenting the DER option to utilities, as they need to understand clearly what DER is going to mean for their bottom line. Standardized tests and connections are necessary for utilities to feel comfortable with DER. Some suggestions were labels on the unit for utility workers, standardized plugs for utility testing of the DER units, and standardized lists of tests for which the DER units must be able to provide information. It was commented that Capstone has just placed an item in its microturbine that the utility can plug into and immediately test unit relays. This was done in response to utility desires to be able to test the unit itself.

Standardizing communication interfaces can be complicated by a utility’s desire to retain its own SCADA system. Therefore, any conversation about interface standardization must include input

from utilities as to their interest in and willingness to use it. It was mentioned that there currently is little cost incentive, or perception of cost incentive, to encourage the utilities to change their set ups. They need financial and other numbers about DER usage in order to pique their interest in the technology.

Participants noted an often unanticipated result of DER interconnection. DER units, supplied with testing and monitoring systems, are often able to highlight and report problems with or errors on the grid. Whether this detection is a positive or a negative from a utility perspective differs greatly depending on circumstances.

## TECHNOLOGY CHALLENGES AND R&D SOLUTIONS

### **Presentation**

The second session began with a presentation by *Dr. Robert Wills, P.E., Advanced Energy, Inc.*, “Universal Interconnection Technology.”<sup>10</sup> Several points were made in the course of the presentation. These included:

- Security, rather than economics, may currently be the strongest driver behind DER.
- DER efficiency levels must improve.
- The issue of multi-inverter islanding is not addressed in IEEE P1547 and may be an issue in UIT development.
- Concerns were expressed about the sufficiency of UL 1741. Dr. Wills commented that tests for this standard should be method tests rather than a performance test.
- Grid stability can be threatened by the opposite direction flow of energy from DER.
- There is a need for a utility lockable disconnect.
- He listed functions of Advanced Energy’s latest generation inverter controller. These functions included:
  - Static trips (V/F)
  - Anti-islanding
  - HMI (Human Machine Interface) - LCD
  - Datalog/ RTC (4MB)
  - Redundant voltage measurement
  - Multigrade energy measurement
  - RS-485 Communications
  - Open (Sandia) protocol
  - IN-CCT Programmable

Workshop participants then asked a series of questions and commented on the presentation. These questions and comments included:

- It was noted that the anti-islanding primer list included in the presentation is not exhaustive.
- It was further noted that much of the risk associated with islanding were theoretical. The question was then asked: since the risk is small, is it an acceptable level? Will this be an academic question for the next while? Though addressed by Dr. Wills and the participants, this issue went unresolved.
- As a result, a suggestion was made for a separate conference on the islanding issue.

### **White Paper**

Dr. Wills’ White Paper follows and his Presentation is included in Appendix A.

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<sup>10</sup> Dr. Will’s presentation is available in Appendix A.

**Dr. Robert Wills, P.E., Advanced Energy, Inc., “Universal Interconnection Technology.”**

## **Universal Interconnection Technology Technology Roadmap Workshop**

July 25, 2002

Dr. Robert Wills, P.E., VP Engineering, Advanced Energy, Inc.  
Wilton, New Hampshire

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### **Introduction**

It is important to understand *why* we want Distributed Energy Resources (DER), so that we can best establish *how* to implement them.

In 1973, E.F.Schumacher said in his classic book, *Small is Beautiful*:

We need methods and equipment which are:

- Cheap enough so that they are accessible to virtually everyone;
- Suitable for small scale application; and
- Compatible with man's need for creativity

*Small is Beautiful* is the underlying philosophy behind Distributed Energy Resources. Thirty years later, however, there are additional reasons for adopting this technology.

The foremost of these now is security – which may be divided in to three areas - power reliability, power quality and immunity from attack. The National Research Council in a recent report to Congress and the Department of Homeland Security has recommended that we “Develop, test and implement an intelligent, adaptive electric-power grid”:

Recommendation 16: Technology should be developed for an intelligent, adaptive power grid that combines a threat-warning system with a distributed-intelligent-agent system. This grid would be able to rapidly respond with graceful system failure and rapid power recovery. It would make use of adaptive islanding—a concept employing fast-acting sensors and controls to “island” parts of the grid as the rest comes down—and technologies such as storage units positioned at key points to minimize damage during shutdown. The system would need to be able to differentiate between a single component failure and the kind of concurrent or closely coupled serial failures at several key nodes that would indicate the onset of a concerted attack.

The following was reported in the LA Times, and on CBS News:

--1 July 2002 Attacks on Power Companies Growing

Power companies are increasingly being targeted by hackers, according to data gathered by RipTech. FBI spokespersons expressed concern.

Another reason is the environment. We know that atmospheric pollution from power plants is contributing to global warming. New technologies such as fuel cells offer much cleaner ways to generate electricity. Schumacher said:

Small scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature.

Further, we are using our natural capital (i.e., coal and oil) instead of changing to sustainable energy systems. Again, from *Small is Beautiful*:

It is clear that the “rich” are in the process of stripping the world of its once-for-all endowment of relatively cheap and simple fuels.

Distributed Energy Resources also promise lower energy costs by having lower initial design costs, shorter time to market, standardized components, higher efficiencies (which still need to be demonstrated for most technologies), heat recovery (also known as Combined Heat and Power, or CHP), storage (for Distributed Energy Storage devices) and lower distribution losses (as electricity is generated near its place of use).

The main impediments to the wide-scale implementation of DER have been cost, immature technology, and safety concerns – will a DER device energize a section of the grid (i.e., form an island), will it damage utility or consumer equipment, can it disrupt power quality or reliability?

In summary, to make Distributed Energy Resources fully viable, we need to make these devices:

- Secure (providing reliable, high quality power and immunity from attack)
- Flexible (capable of feeding the grid and operating in intentional islands)
- Efficient and Cost-effective
- Renewable and Sustainable
- Safe

## Interconnection Technology

In the technology area, many issues have been solved:

- IEEE 1547 will become a national standard for characteristics such as voltage and frequency trip setpoints and islanding performance
- Current-controlled inverters are well understood – the quality of the power generated by DER systems is satisfactory.
- Adequate anti-island techniques have been developed.

Other issues are still open:

- Multi-inverter islanding has not been addressed.
- Methods of controlling microgrid and intentional islands need to be developed and standardized.
- Well defined procedures are needed for testing to minimize time to market and costs, and to ensure reliable results.
- The possibility of DC being fed onto the grid needs to be addressed.
- There is a need to certify controllers, control schemes and controller code rather than individual inverter models (we believe that this is a key to universal interconnection).

Finally, there are myths that need to be dispelled, for example:

- Voltage and frequency protective relaying alone can provide reliable anti-islanding protection. Protective relays are still considered acceptable by many utilities.
- UL1741 island tests are sufficient to ensure multi-inverter protection
- Induction generators cannot island.
- Islanding is unlikely to occur. This is true for properly designed inverters – but islanding is actually very likely to occur if anti-islanding schemes are not implemented well.
- Line workers are endangered by islanding. Standard procedures, which are carefully followed, require disconnection, test and grounding of equipment before any work starts.

## Islanding

The basic theories of island prevention are now well understood. We believe that the problem is essentially solved.

Advanced Energy introduced the ideas that now are accepted as best practice in the USA (real and reactive power feedback schemes), and has been granted a broad patent on these concepts. The Patent covers feedback and acceleration methods which are also known as the Sandia Voltage and Sandia Frequency Shift techniques (SVS & SFS).

There is still however work to be done: we need to prove the viability of island prevention techniques at high penetration levels, we need to model stability in the wide-area grid as penetration increases and we need to model and test multi-inverter systems and various methods operating together.

There is also a need for standardized test methods that clearly identify test setups and procedures. An example of this is the current question as to whether Sandia’s test equipment (with iron cored inductors) differs significantly from UL’s test setup (with more linear, but higher loss air-cored inductors). Finally, there is a question as to whether we should test with rotating machine loads, even though there is strong evidence that induction motors will not support islands any more than an equivalent compensated RLC circuit.

## Anti-Islanding Primer

The following is a brief summary of the various methods that are used for island prevention.

### ***Passive Trips (Voltage and Frequency)***

If the grid voltage or frequency goes outside set limits, the inverter stops exporting. This is sufficient to prevent islands where there is real or reactive load mismatch. As the load will respond to Ohm’s Law (voltage = current x impedance), the allowable limits translate directly to the possible islanding load range.

### ***Phase Jump Detection***

Phase Jump Detection causes a shutdown if a sudden change in phase of the grid voltage waveform is seen. It was used successfully in early U.S. inverters such as the APC Sunsine. It suffers from two problems – sudden voltage phase changes can occur on a normal grid if low power factor loads such as induction motors come on line (leading to false trips), and a well matched load will not create a phase jump upon loss of grid (leading to a non-detect zone).

### ***Harmonic Monitoring***

This technique was popular for a while, but relying on either ambient grid harmonics or high frequency signals generated by the inverter is subject to wide variability, especially if other noise sources or harmonic traps such as power factor correcting capacitors are present.

### ***Impedance Measurement/Power Shifting***

Impedance measurement and power shifting are essentially the same – if we change the output current and observe the resulting voltage change, we are measuring impedance. The problem with simple impedance measurement is that if multiple inverters are used, and the power shifts are not synchronized then the voltage change in response to a current change will be diluted by the number of inverters on-line. If they are synchronized then flicker problems are likely. It is generally accepted that simple power shifting techniques are not adequate in multi-inverter installations. The German ENS system is an impedance measurement system.

### ***Frequency Bias***

These methods generate a current waveform that is slightly higher or slightly lower in frequency than the observed voltage waveform frequency. They fail at high Q's where the frequency bias is overcome by the load phase characteristic and also require a decision as to whether to always go up, or to go down (which may be conflicting in a multi-inverter situation).

### ***Real Power Feedback***

This method responds to small changes in grid voltage by making a change in output current that would result in an even bigger change in voltage, should an island exist. This is also known as the Sandia Voltage Shift (SVS) method. After a few cycles, the inverter stops with an upper or lower voltage trip. When carefully implemented, this technique can provide reliable island protection in both the single and multi-inverter cases.

### ***Reactive Power Feedback***

Reactive power feedback is similar to real power feedback – the reactive power output of the inverter (or phase or shape of the output current waveform) is changed in response to an observed change in the operating frequency of the inverter. As the inverter load in an island situation can be modeled as a parallel RLC circuit, changing the inverter's reactive power output is the same as adding inductance or capacitance to the RLC tuned circuit, and thus changing its resonant frequency. After a few cycles, the inverter stops with an upper or lower frequency trip. This technique is also known as the Sandia Frequency Shift (SFS) method. It can be combined with the real power feedback method and will provide reliable island protection in both the single and multi-inverter cases.

### ***Direction & Acceleration***

Two other concepts were introduced in our patent: First, the direction of the power or frequency response should be in the same direction as the observed change on the grid (and so in the same direction as other inverters). This overcomes the problem of deciding whether to bias up or down in frequency or power. We call this *following the herd*. The second concept is *acceleration* – if the voltage or frequency continues to change in the same direction, the magnitude of the response is increased exponentially each time. This results in faster trip times, lower initial response values and undetectable flicker levels.

## Islanding - Known Problems

### ***Non-detect Zones***

Professor Michael Ropp’s work in modeling frequency bias schemes showed that these, and most other non-feedback techniques, suffer from Non-Detect Zones (NDZ) in the load impedance plane. For example, power shifting will not detect inside the allowable grid voltage limits, and frequency bias will not detect if the load  $Q$  exceeds the slope of the inverter phase/frequency characteristic. Recently, we have discovered other non-detect areas related to thresholds, and measurement and output resolution.

### ***Flicker***

Any method that causes changes in inverter output power may result in flicker problems. The change in output must be carefully balanced with respect to flicker and anti-island sensitivity. The voltage and frequency feedback methods do not have flicker problems if acceleration is used – typical output current variations are of the order of 0.5%, which is the output control resolution of the inverter.

### ***Dilution of power shifting methods***

This is discussed above - the voltage change in response to a current change will be diluted by the number of inverters on-line

### ***Thresholds***

Some island protection techniques rely on a measured value exceeding a fixed threshold to initiate a power or frequency change. This can lead to non-detection if the noise level in the island is lower than the threshold. Techniques that rely on fixed thresholds are best avoided.

### ***Measurement Resolution***

Another non-detect problem can come from quantization of input measurements. For example, a voltage feedback scheme that measures grid voltage with 1 Volt rms resolution may not see any changes in voltage once an island occurs, and will not initiate power output changes.

### ***Output Quantization***

If a 1 kW inverter can only control its output in 5% steps, and a 1% change in input voltage is seen, the required output change may be calculated as 2% which is less than the output step size – power feedback will only start if a voltage change of 2.5% is seen. This is another form of threshold NDZ.

### ***Incompatibility of Different Methods***

The largest unknown in islanding is how different methods will interact. For example, how will a voltage feedback scheme work with a power-shifting scheme? Much depends on the number and size of inverters of each type.

Some combinations are clearly incompatible – a frequency-shifting scheme that pushes up combined with an inverter (or perhaps a motor load) that is pulling down, for example.

## Islanding Conclusions

We believe that our real and reactive power feedback methods are presently the best possible techniques for island prevention.

Because of the potential for incompatibility between different methods, we believe that a standard anti-islanding method, not a performance test, should be adopted. A standard method would also lend itself to certified inverter controllers.

Finally, we must base future work on theory, not on experimentation. We should use understanding and accurate computer models to establish the viability and reliability of our islanding protection schemes.

## **DC Injection**

Many inverter designs can inject DC onto the line. For example, a half-bridge inverter such as the older Omnion design with a shorted IGBT (and probably also a control system failure that allows the AC contactor to close) could connect 400V DC from a PV array directly to a 120V distribution line. There may be industrial or commercial equipment that could create the same hazard on multi-phase systems – for example, rectifiers, motor drives and welders. Incorrect installation could create this hazard even with a transformer-isolated inverter if a DC input wire came loose and shorted to the output.

High voltage DC could be very hazardous to a line worker who is only equipped with AC measuring equipment. Because of this, there is an urgent need to alter utility test procedures. A compensating factor is that this problem could only occur at the level at which the inverter is connected (typically the distribution transformer secondary), and so precautions would not be needed at the medium voltage distribution level.

Some utilities are questioning non-transformer-isolated designs, but this is more from a concern of saturating distribution transformers than of creating a safety hazard. There is a need to distinguish between high frequency isolation transformers in DC-link inverters (that still have high voltage DC outputs) and low frequency isolation transformers.

We need to establish minimum monitoring and protection requirements (such as checking for DC voltage components on the inverter output) for inverters that do not use low-frequency transformers.

## **Microgrids and Intentional Islands**

The National Research Council recommended that we develop an intelligent, adaptive electric-power grid. This means that DER devices will not only need to export power to the normal grid – they must also be able to support an intentional island.

We need to agree on how devices will work together via communications and their electrical interface. We must allow for steady state, transient and fault conditions, and also for non-unity power factor and high harmonic loads.

We must also develop schemes for dispatching devices both in minigrid and normal grid-connected modes. For example, in a minigrid, we should run just enough generation to satisfy the load, and recharge energy storage.

AEI has been working on these and related problems for three years with the Sandia Energy Storage group.



## Certified Controllers

Presently, the cost of listing an inverter with Underwriter’s Laboratories is very high, and is increasing (it is typically \$50 to \$100K per inverter). Much of this testing is to verify the anti-islanding performance of the inverter. Tests are required at 25, 50 and 100% of inverter rating with high Q RLC matched load (100% resistive, 250% inductive and capacitive).

This testing could be eliminated if the anti-islanding method was completely understood and if the behavior of the inverter controller was fully tested and certified.

From both the manufacturer’s and the utility’s point of view, it would be far preferable to have one certified controller than ten different inverter models.

The functions tested in a certified controller would include:

- Under and over voltage and frequency trips
- Active anti-islanding scheme
- Power quality (to be re-tested on each inverter version)
- Intentional-island support mode
- Mode transitions
- Safety shutdown behavior
- Watchdog functionality
- Non-volatile setpoints
- Calibration accuracy and reliability
- Dual redundant grid voltage sensing
- Communications protocol compliance.

We believe that this is a major step on the path to universal interconnection technology.

## Communications

DER communications are required for performance monitoring, remote diagnostics, and control/dispatch functions. Even though a well-designed DER system should be able to operate autonomously, remote communication is necessary to allow the full benefit of DER (especially dispatch based on real-time pricing) and to minimize field service costs.

The IEEE recently approved the formation of a working group for P1614, *Draft Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems*. This working group will be the focus for DER communications work.

Key areas in this work are:

- Protocol definitions (it is likely that multiple protocols will be supported including existing utility SCADA protocols). An XML protocol is also likely to be supported.
- Object Models (data description models for inverters and generation and storage devices).
- Security (data encryption standards, key management, authentication).
- Threat analysis and warning (as identified in the National Research Council report).

As communications controllers must be very low cost, especially for the smaller DER systems, an important area that requires development is encrypted protocols that are adequate, but simple enough to be implemented on low-end microprocessors. Software to implement standard internet (TCP/IP) communications on low-cost microprocessors is readily available, but cryptographic security protocols such as the Secure Sockets Layer (SSL) are presently not.

## Conclusions

The key areas that we have identified for research towards a Universal Interconnection Technology are:

- A standard anti-islanding method that is proven in the multi-inverter case
- Control schemes for microgrids and intentional islands
- Certified controllers
- Test procedures
- Communications protocols and object models
- Cryptographic techniques such as SSL for use in micro-controller-based DER communications devices.

*There is a wisdom in smallness if only on account of the smallness and patchiness of human knowledge, which relies on experiment far more than on understanding.*  
(E.F. Schumacher)

## ***Technology Challenges and R&D Solutions: Participant Discussion***

The general reaction from industry was that UIT is needed for and would benefit the adoption of DER within the electric infrastructure. There are further benefits to be gained through the development of a modular UIT. Understanding the modular concept and how it might be used in designing a UIT is an important step towards achieving these benefits.

A group discussion was initiated to address these issues, and the following questions were presented:

- What benefits might accrue from a modular design?
- Does a modular design produce benefits when different companies work on components of a UIT?
- How might the basic functions of a UIT be organized into a block diagram (modules)?
- Examining the list of UIT functions, would there be any differences by size?

### **UIT Modularity**

*What benefits might accrue from a modular design?*

The group discussion began by asking participants to discuss the benefits of a modular design. The list below was generated by participant comments.

- Modularity is good if it is done right. It is important to look forward.
- From a manufacturer's view, modularity is beneficial from both cost and niche marketing perspectives.
- With modularity, customers do not have to pay for a multi-MW machine's worth of components for, e.g. a 100 kW machine. Using the computer analogy, it is like not having to buy a super high powered computer if all you want to do is use a word processing program.
- No two systems are the same, modularity allows selectability based on size and other system characteristics.
- It is important to know what customers 1) Need, 2) Want, 3) Would like to have in determining the progress of the modular design and of components over time.
- Modularity enables other abilities.
- Software modularity keeps costs down for smaller units, while the software based components keep costs down for manufacturers.
- Modularity allows mass customization.
- Modularity has costs, as it can limit the supplier finding the most efficient way to solve a problem. The process must look at company core-competencies, and use modularity only in interfaces with areas outside this core.
- It is necessary to clearly define a common platform to which companies can add.
- Contractors want a package that works, as they have little interest in doing detailed engineering.
- Modularity may work when the market is young, but after building a certain number of units, will companies just start producing a set product to target to market niches with options included automatically? This is an important point to consider when anticipating gains from modularity.
- Modularity's value depends on the expected life-cycle of the product. If the life span is short, then you must be able to easily upgrade it. In this instance, modularity is important.

However, for high capital products expected to last for the life of the facility, modularity is not important since the system is only required to interface with the outside world.

- Has the definition of modularity changed over the last several years? Now that software is so important, we must be sure to look at software modularity.

Participants were unanimous in their support of standardization of UIT interfaces and the specifications of UIT functions. In contrast, participants were firm in their belief that the components and software packages should not be subject to standardization.

## **Benefits to Multi-Source UIT Component Manufacturing**

*Does a modular design produce benefits when different companies work on components of a UIT?*

It was noted that modularity drives lower costs, and addresses customer concerns about being tied to one supplier.

As an outcome of discussion, it was agreed that there are significant benefits to be had for businesses from building a modular UIT.

## **UIT Block Diagrams**

*How might the basic functions of a UIT be organized into a block diagram (modules)?*

A series of example module block diagrams were presented and discussed, including a diagram presented by Dr. Sam Ye of GE Global Research Center, a diagram from Resource Dynamics Corporation, and a diagram developed by Joe Koepfinger of Koepfinger Consulting. Initial group comments included:

- Too little focus is placed on synchronous generators in favor of inverter based systems.
- Diagrams should be technology neutral.

As part of the discussion, the group determined that although a comprehensive diagram must still be developed, the diagrams presented provide a starting point for discussions of modularity, functions, and interfaces. The group agreed that the yet to be developed UIT block diagram will likely include the following:

- Two paths (or subsystems) were identified: 1) Power subsystem or path; and 2) logic and control path – with communications and data links between the two paths.
- 6-7 interface points.

A key component of a UIT is having a controller that has a standardized interface with the other components of the interconnection system, so that different manufacturers' controllers would be interchangeable, providing flexibility, expandability and second sourcing.

Of particular interest from the GE diagram was its representation of standardized/ normalized interfaces (see Figure 4). This diagram also carried the "two basic modules" concept, naming these the IED (intelligent electronic device) and the PCD (power carrying device).

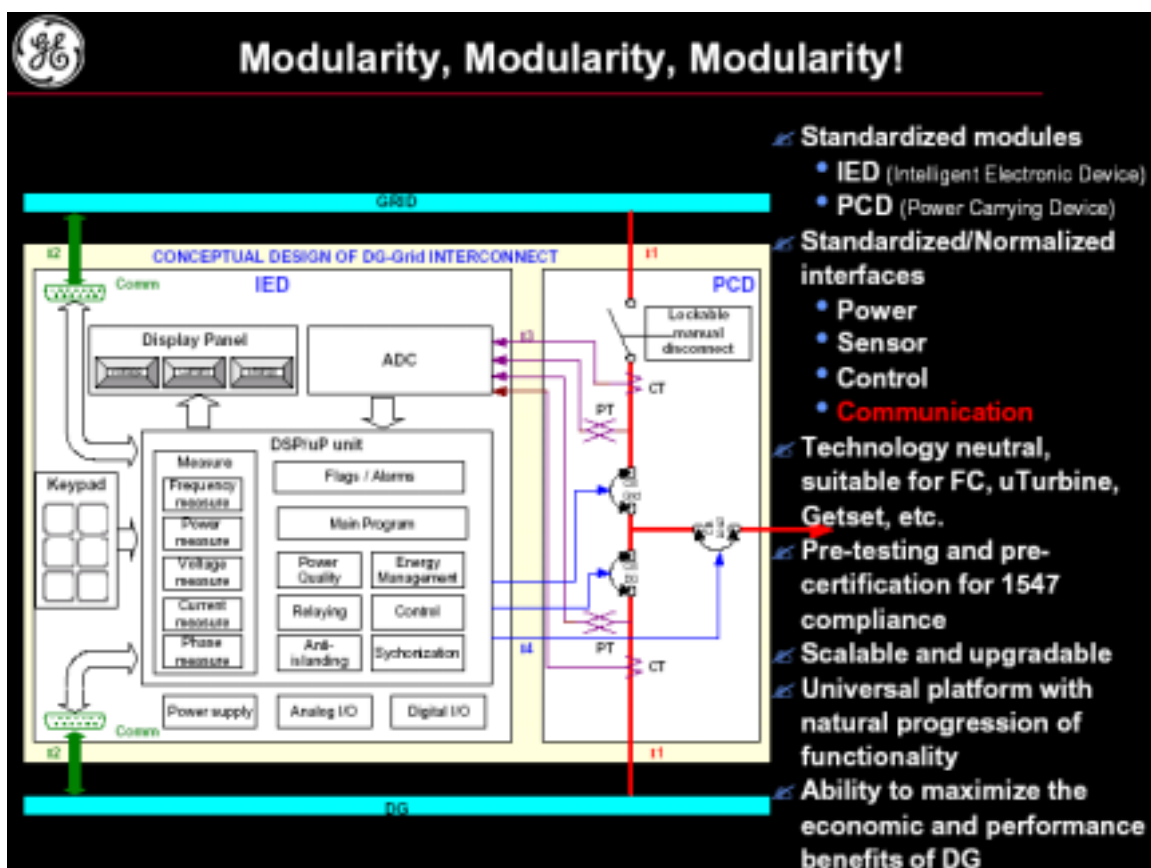


Figure 4. GE Modular UIT Block Diagram.

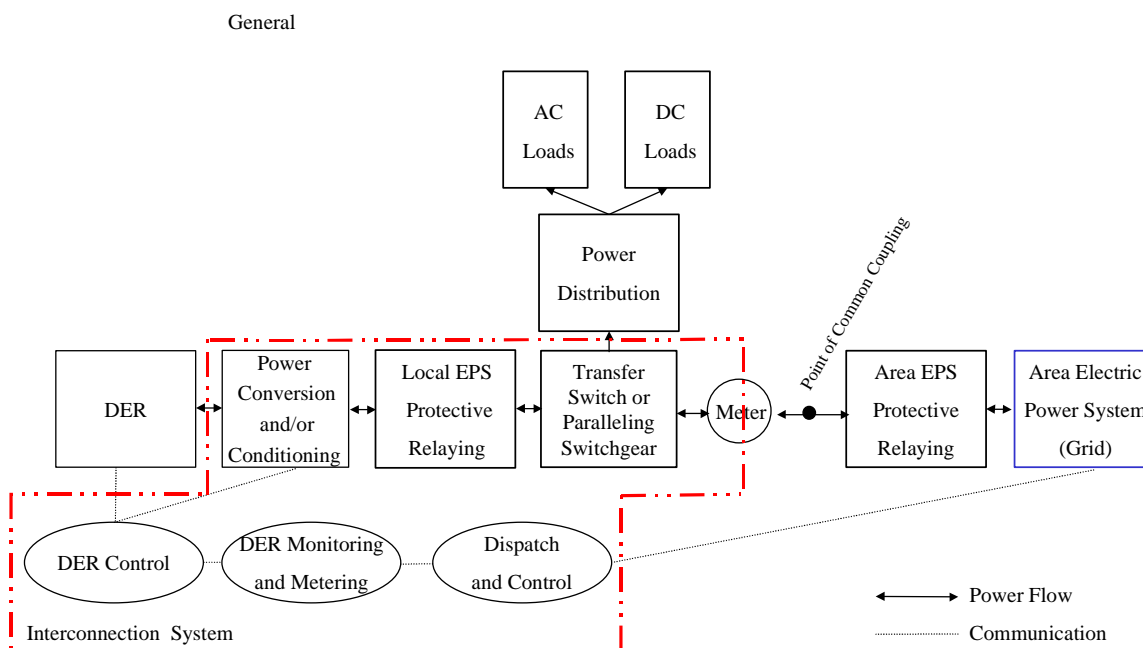
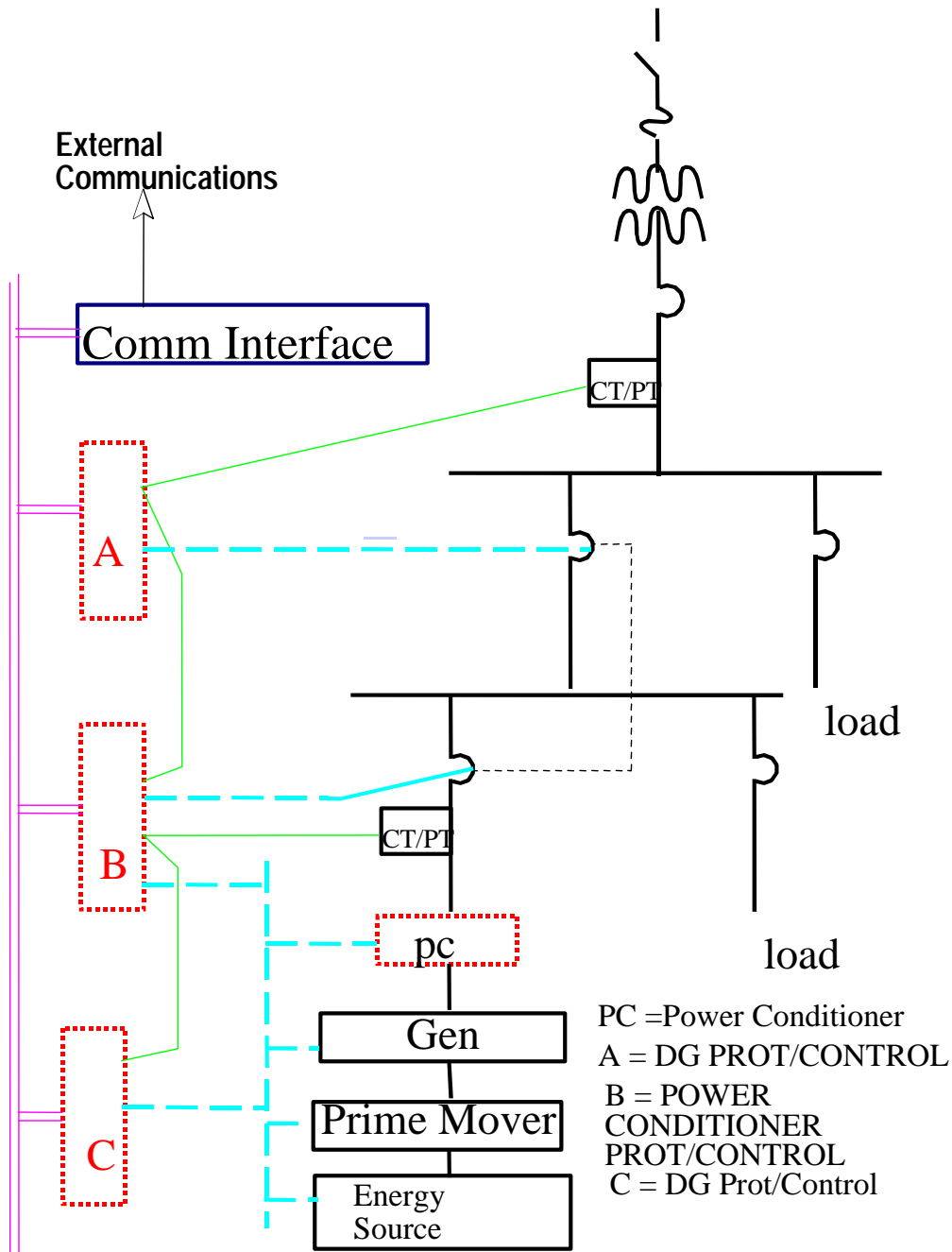


Figure 5. Resource Dynamics Corporation Modular UIT Block Diagram

The Resource Dynamics Corporation's version of the Modular UIT incorporated a 2 track design, illustrated in Figure 5 as a Power Flow and a Communication Flow.



**Figure 6. Koepfinger Modular UIT Block Diagram.**

Mr. Koepfinger's block diagram, shown in Figure 6, was well received by the group. He represented the UIT with a common bus structure as another example of interface standardization. The diagram depicts both optional and required items. These include:

- Red/ short dashed optimal items to be included somewhere in the UIT.

- A common data box that the DER would plug into and a common protocol.
- Control systems that can be either independent or dependent. Blue/ long dashed lines indicated data lines and control lines.
- Communication systems.
- An optional power conditioner.

Mr. Koepfinger indicated that this diagram was his way of capturing the first day's discussions of functions and features. Functions can be placed in any of several physical boxes or into one box. In addition, as far as the boxes are concerned, each could be produced by a different manufacturer or all produced by one manufacturer. The diagram is representative of a concept rather than suggestions for building an actual UIT.

Group comments included:

- Diagrams need to distinguish between DER and EPS protection, as the concern of the DER owner will be protecting that asset.
- The data communicated and the speed at which it is communicated varies by installation. It can be a large quantity of data at very high speeds or the simplest of control and communications.
- This diagram represents a single unit installation. With higher penetration, you simply expand or duplicate your UIT. It is important now, though, to just look at the fundamentals and the bottom most requirements. That way if you have multiple units, you know at the very least you can just put in multiple UITs.
- Some participants believed communications to be optional.

Participants were cautioned again that these figures are representations and ideas. More discussion will be necessary to capture in a standard format the UIT concept.

## UIT Functions and DER Size

As shown in Figure 7, many sizes of DER are being interconnected. As a result, participants were asked the following question:

*Examining the list of UIT functions, would there be any differences by size?*

- Participants indicated no differences in functionality based on the size of the DER unit.
- Though basic functionalities remain the same, decreasing costs is critical as this in turn lowers the size of the DER that can economically be interconnected.
- Net metering for small units, and better controls for large gas turbines were both considered additional capabilities, not basic functions.

### CA Interconnection Requests Nov 2000 - May 2002

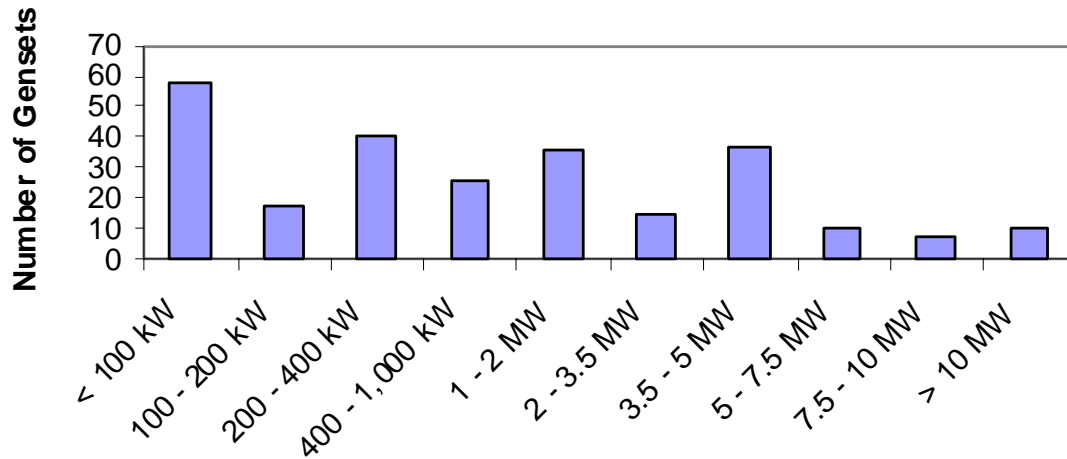


Figure 7. DER Interconnection Size Ranges

### Feasibility and Potential Roadblocks

Key points and insights from this discussion included:

- Object models will be important for self-configuration and plug-and-play operation.
- Utility acceptance may depend on familiarity – providing a single way to interface and test from a utility point of view, i.e., standardization.
- Industry participants expressed a strong opinion that the application firmware/software should not be standardized, since this is critical to product differentiation and protecting the companies' proprietary property.



## MOVING FORWARD - NEXT STEPS FOR THE UIT DEVELOPMENT AND WRAP-UP

After two days of discussion, the general reaction from industry was that a UIT is needed for and its adoption would result in increased use of DER within the Nation's EPS. Achieving the goal of a modular UIT will require planning and effort over the next several years by members of industry and the U.S. DOE.

In order to build a foundation for moving forward with UIT development, Workshop participants were asked the following questions:

- What are the next steps to progress the UIT development effort?
- What approach might we use to accomplish these next steps?

Participants supported the concept of a UIT and felt that its adoption would result in lower costs for interconnection and increased use of DER. The group identified a series of "next steps" for moving forward with the development of a UIT. Amongst the suggested steps were:

- Develop working definitions for each of the UIT functions identified at the workshop so that everyone understands what is being discussed (separating basic functions from optional additional capabilities).
- Develop a list-serve of reviewers.
- Distribute the function and feature definitions via the list-serve and collect and synthesize comments into a clear definition of what a UIT device should include.
- Collect customer input on what their requirements for a UIT would be. This may include DER installers, utilities and PUCs.
- Convene a one-day workshop with a synchronous design group with a mandate to develop a UIT requirements document. This group would:
  - Determine what common building blocks might exist in a UIT for synchronous machines.
  - Develop a draft version of UIT diagrams (with functions, modules and interfaces) for alternative DER applications.
- Convene a one-day workshop with an inverter design group with a mandate to develop a UIT requirements document. This group would:
  - Adapt and modify the synchronous UIT diagrams as necessary to the inverter situation (with functions, modules and interfaces) for alternative DER applications.
  - Determine what common building blocks might exist in a UIT for synchronous and inverter machines.
  - Develop an expanded UIT requirements document.
- Convene a two-day workshop of the combined synchronous and inverter design groups to discuss and resolve differences in the requirements documents and UIT diagrams.
  - Further define the individual pieces within each UIT block diagram.
  - Define the interfaces between each common building block piece, especially noting any parameters that may influence standards development.
  - Determine how to best work with standards organizations to move towards the adoption of and/ or inclusion of the design groups' technical requirements document into new UIT standards and protocols, as well updating other relevant standards documents.

Possible additional steps could include:

- Develop and distribute educational materials to stakeholders.
- Develop interconnection case studies.
  - Especially those that show interconnection costs, as the lack of quantified data regarding interconnection costs was cited as a barrier to DER.
  - Getting rid of the unknowns of cost would be especially beneficial for smaller projects, as they cannot afford to spend much more than a few days on answering these questions.
- Work with stakeholders to develop type-testing certification processes.

Prioritizing and streamlining these steps, group participants developed this series of “next steps” for moving forward with the development of a UIT. These steps include:

### **Next Steps**

- Develop working definitions for each of the UIT functions identified at the workshop.
- Develop functional block diagrams of interconnection systems for a variety of DER configurations to aid in synthesizing the UIT.
- Convene a series of one-day workshops to develop a functional block diagram for the UIT and identification of the core technology.
  - One workshop to develop a functional diagram for non-inverter applications.
  - A second workshop to develop a functional diagram for inverter-based applications.
  - A third workshop to synthesize the inverter and non-inverter diagrams into a UIT and develop a UIT requirements document.
- Develop a roadmap for further defining the individual pieces within each UIT block diagram and the interfaces between them.
- Develop a list-serve for continuing discussion and work on developing the UIT.

Joe Galdo, DOE DEER and Dick DeBlasio, National Renewable Energy Laboratory ended the Workshop by thanking the participants for their input and participation.